The Journal of Bone and Joint Surgery

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The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
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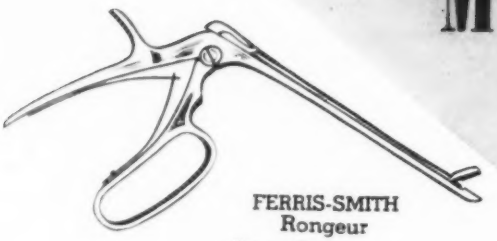

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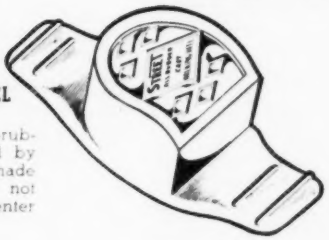

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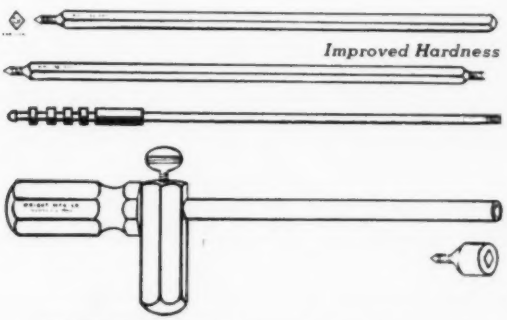

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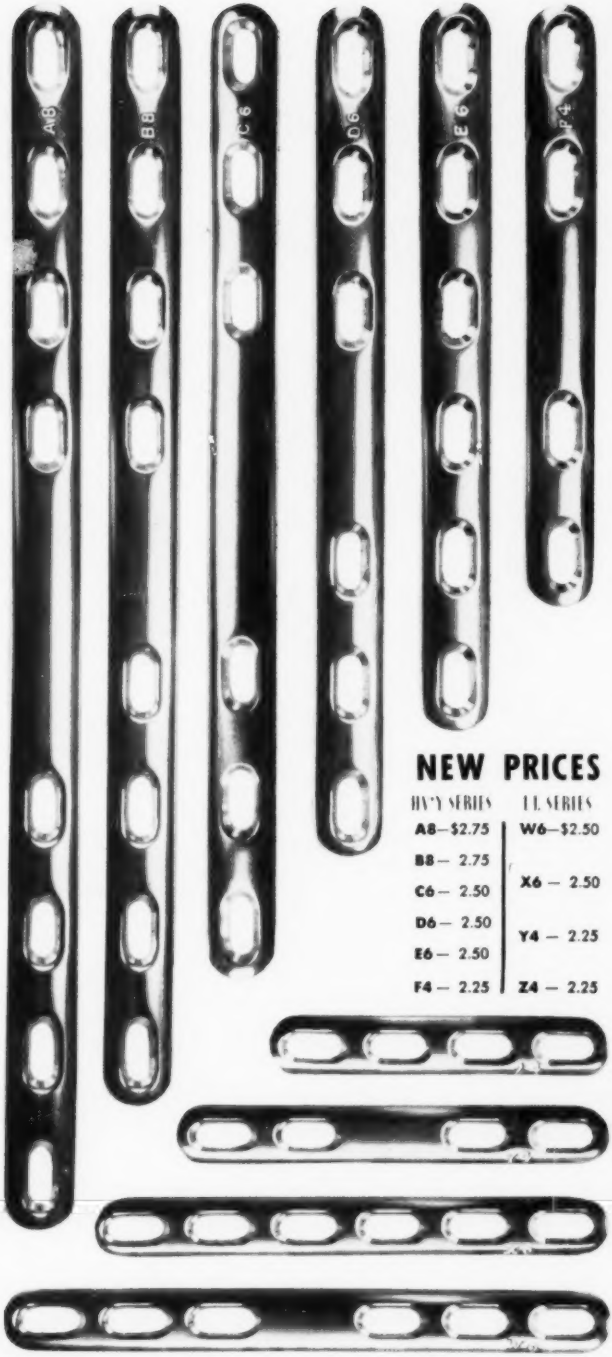

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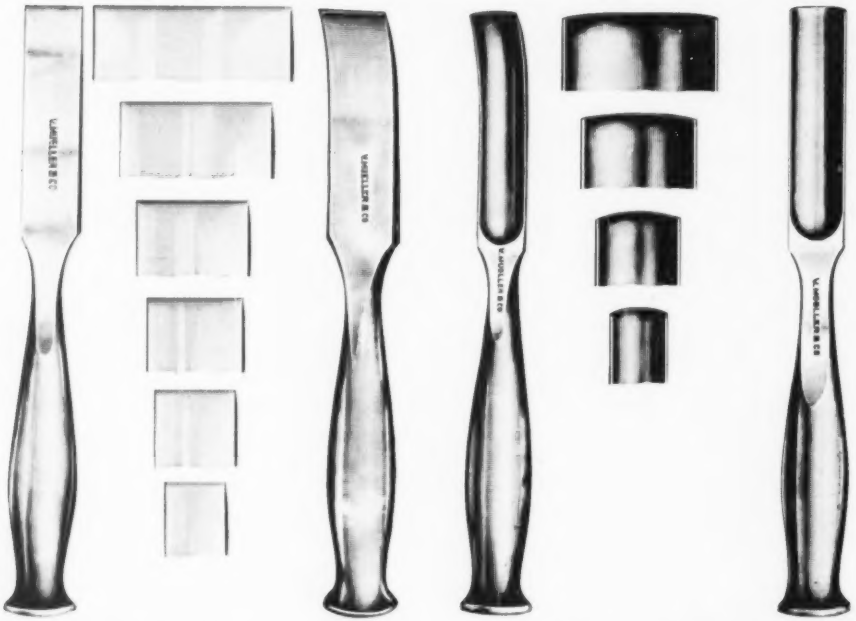

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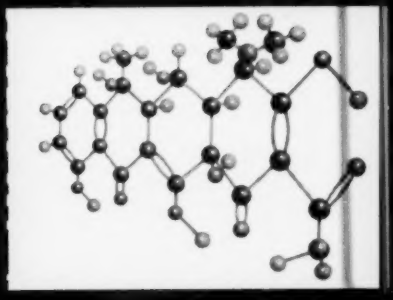

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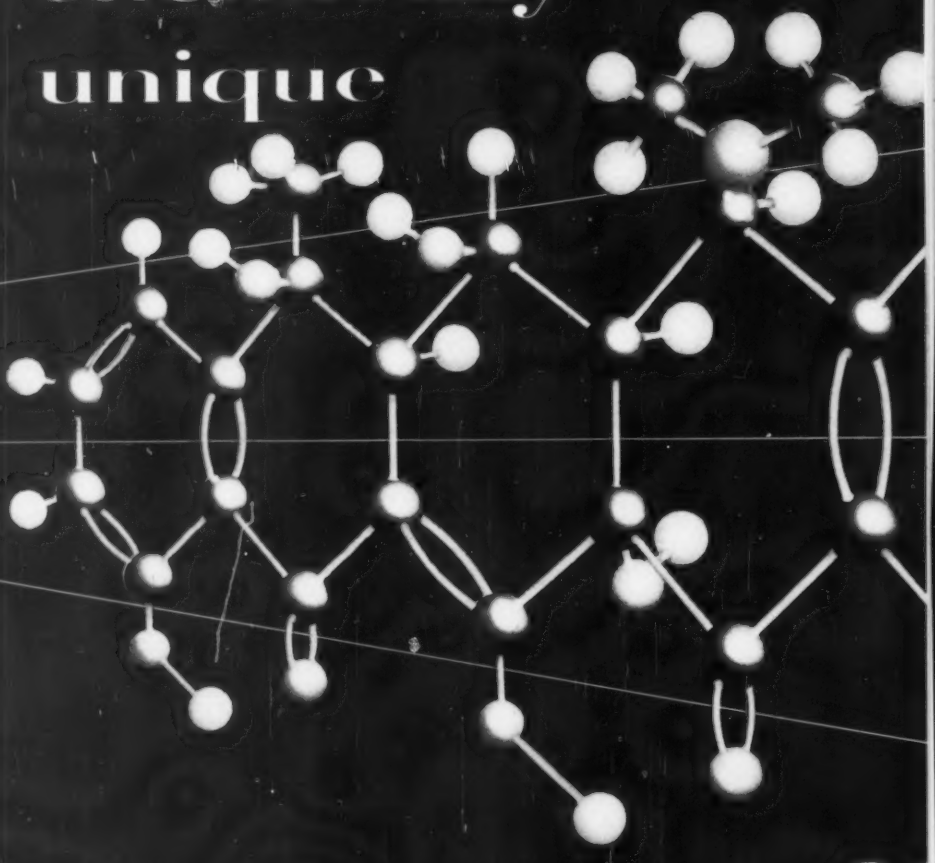

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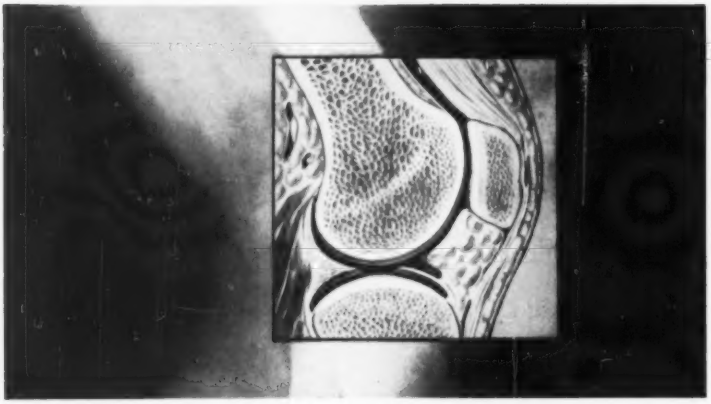

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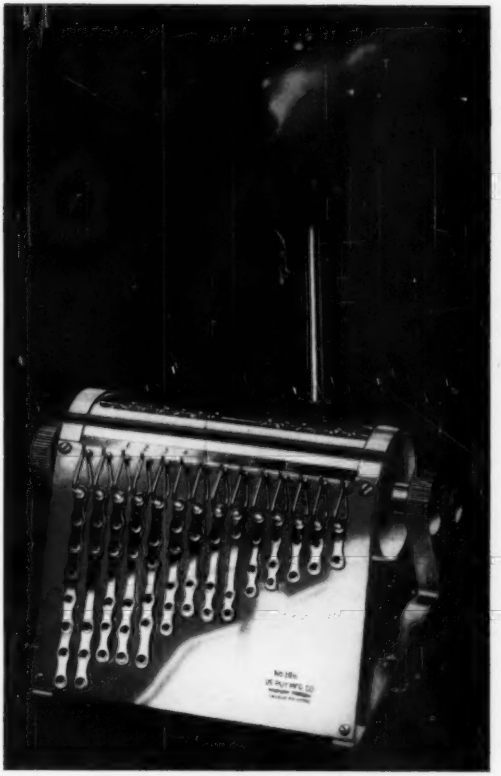

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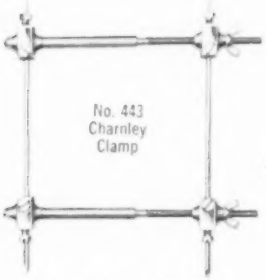

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Orthopedic Surgeons, who have for years been seeking practical, ready-made hip prostheses to replace the femoral head and neck, will find in the six Vitallium hips illustrated here clinically proven prostheses which will help to meet their urgent needs.

Aseptic necrosis, osteoarthritis, ankylosis, ununited fractures, fresh fractures in elderly patients, derangement of the hip joint, and congenital complications are some of the indications for the use of a hip prosthesis.

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A strong and stable appliance with a threaded intramedullary shank to provide wide distribution of weight bearing stresses. The appliance is screwed into place by rotating it back and forth so the self-tapping threads cut their way to a firm seating position. A thread-cutting tap is available to prepare the bone. The greater trochanter is re-positioned over the hook and secured with a bone screw. Two head sizes.

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The oval shoulder and stem transmit weight bearing stresses to the femoral neck and shaft. Available in a right and a left hip style to provide normal anteversion and also in a straight style. There are two head diameters in each of the head styles. A Rasp is available to facilitate preparation of the medullary cavity for close adaptation.

Limitation of space does not permit full description of the salient features of each prosthesis. Write for more detailed information, including size data and suggested operating techniques.

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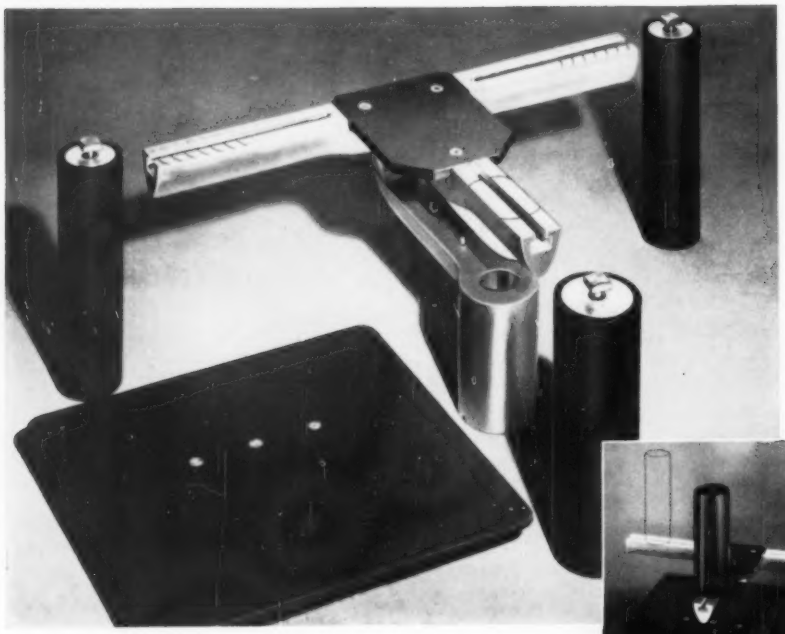

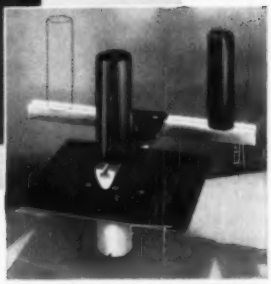

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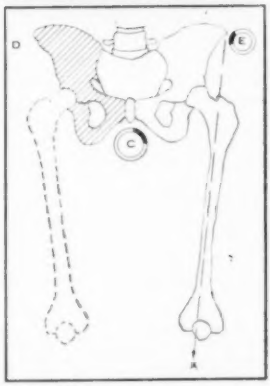

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*Hall, Custis, et al. Jour. International College of Surg.; pp 30-33, January 1952.

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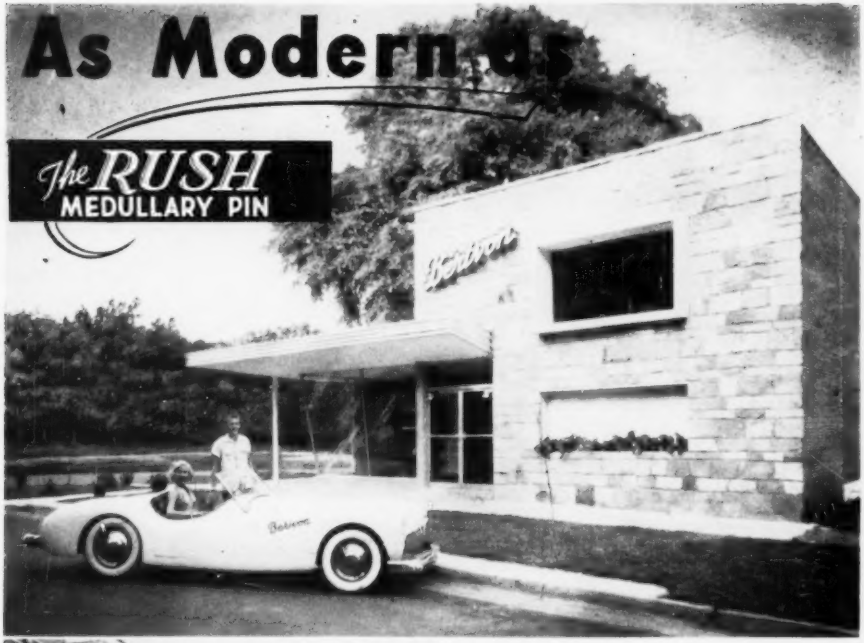

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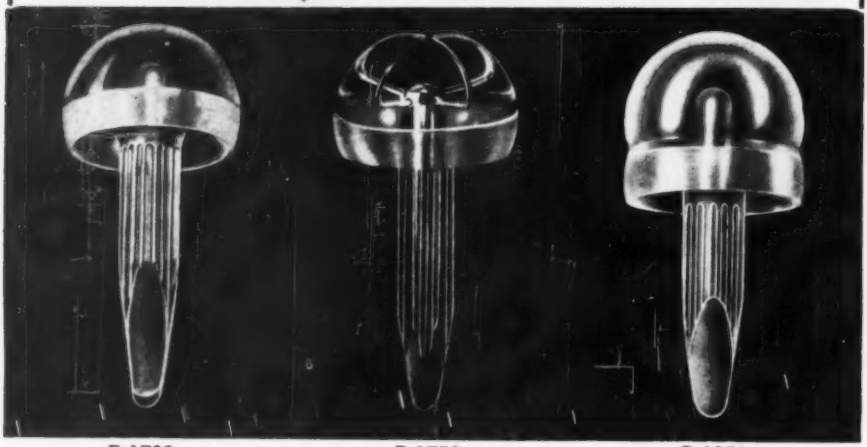

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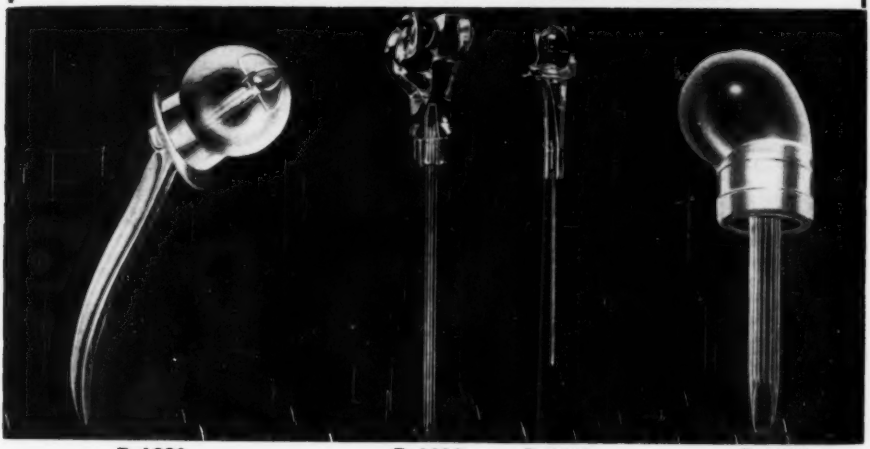

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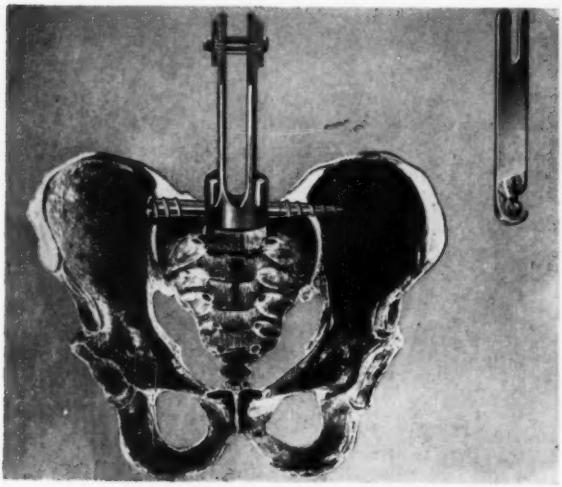

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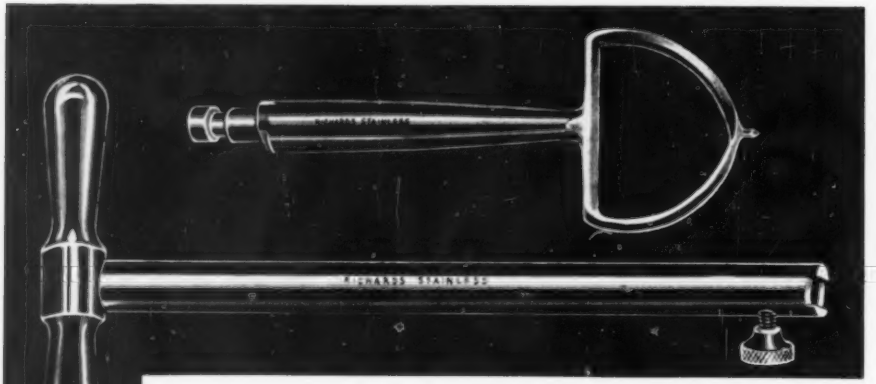

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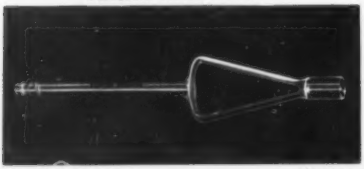

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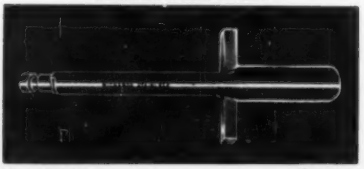

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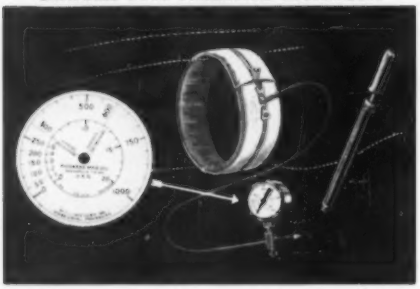

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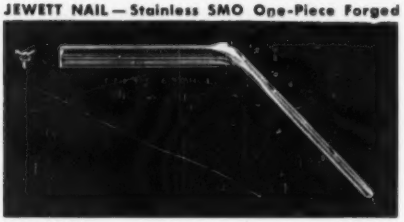

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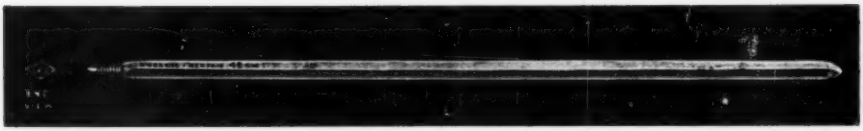

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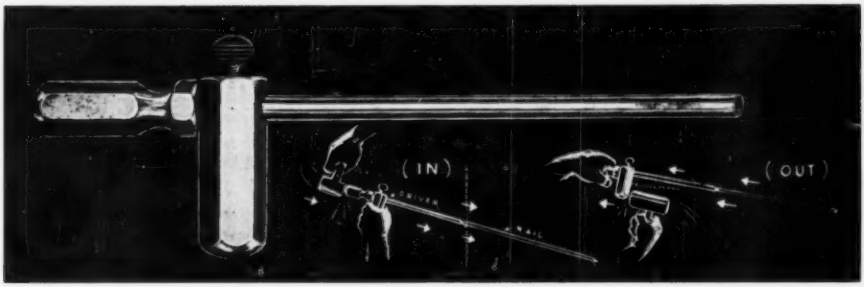

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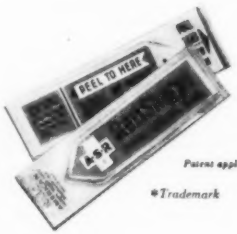

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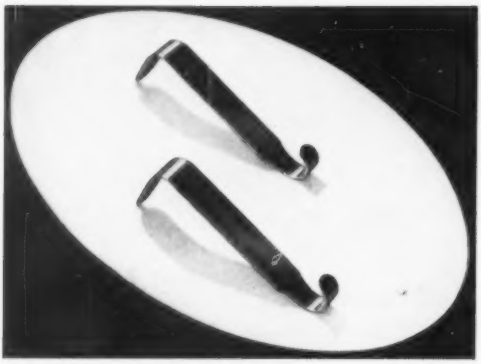

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Cobey,[3] reports not one person allergic to Melmac in applying 1000 casts.

references:

1. A. W. Spittler, Col., (M.C.), U.S.A., J. J. Brennan, Lt. Col., (M.C.), U.S.A., J. W. Payne, Capt., U.S.A.F. (M.C.), American Academy of Orthopedic Surgeons, Jan. 26-31, 1952, Chicago, Illinois.
2. M. C. Cobey, M.D., F.A.C.S., Professor of Orthopedic Surgery, Georgetown University and Senior Attending Orthopedic Surgeon, Children's Hospital, Washington, D.C., The American Surgeon, Vol. XVIII, No. 4, April, 1952, pp. 413, 415.
3. M. C. Cobey, M.D., F.A.C.S., Washington, D.C., private communication.

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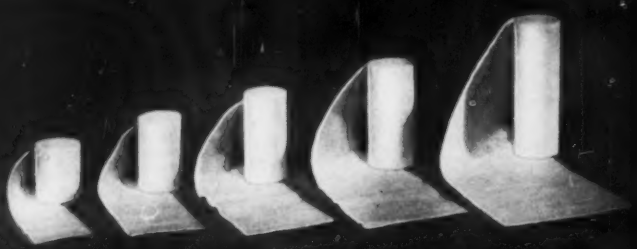

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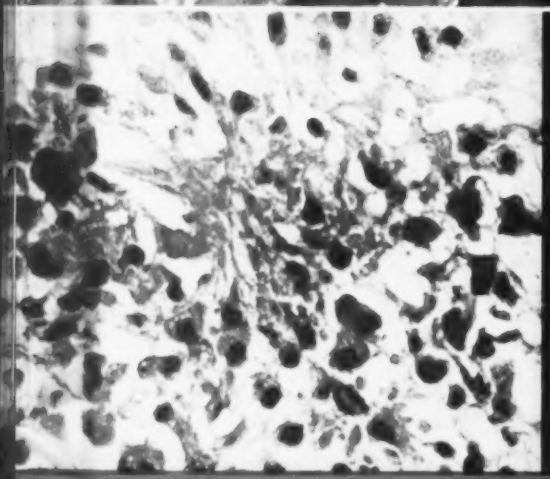
q. Does cortisone influence the heart lesions of rheumatic fever?

a. Early cortisone administration suppresses and in some cases may even prevent serious cardiac damage.



q. What effect does cortisone have on acute rheumatic fever?

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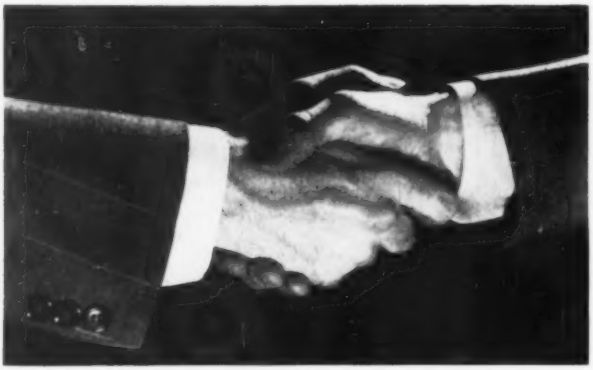

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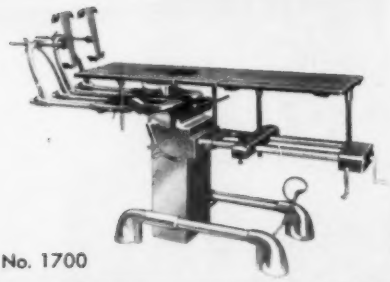

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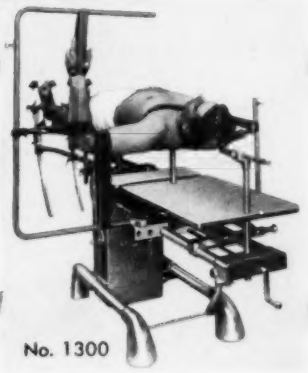

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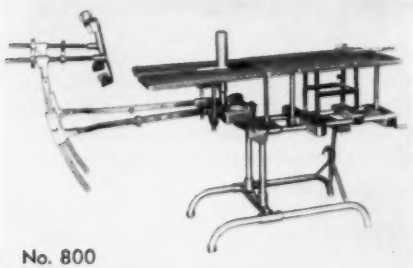

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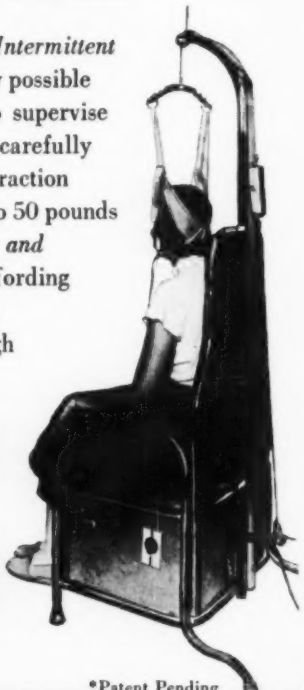

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VOL. 34-A, NO. 4 OCTOBER 1952

The Journal of
Bone and Joint Surgery

American Volume

THE TREATMENT OF BONE AND JOINT TUBERCULOSIS; EFFECT OF 1-ISONICOTINYL-2-ISOPROPYLHYDRAZINE

A Preliminary Report *

BY DAVID M. BOSWORTH, M.D., HOWARD A. WRIGHT, M.D., AND J. WILLIAM FIELDING, M.D.,
NEW YORK, N. Y.

From the Orthopaedic Services of St. Luke's Hospital, New York City, and Sea View Hospital, Staten Island, New York

A definite form of treatment for a specific condition must be judged by results. In biological experimentation such results never reach 100 per cent.; so it is in the use of the new antituberculosis chemicals. Results must be noted, first as to the arrest of the disease process, and secondly as to the prevention of such after-effects as scarring and deformity.

The treatment of osseous tuberculosis by *conservative* means has been carried on over the centuries. *Surgical* intervention, with the suggestion of joint fixation to splint diseased parts, or resection, to remove focal lesions or joint cavities, has been advocated and the results have been studied for forty years. Many forms of *antituberculosis medication* (such as turtle serum) have been tried and discarded. The advent of *streptomycin* marked a tremendous improvement in results, both as to the arrest of the disease and as to lessening of the residual deformity. Six years have elapsed since its introduction, and the considerable benefits obtainable have been well established. The limitations of its use, its failures, and the occasional undesirable results eventuating from its employment have been noted. Often desire has been expressed for the advent of even more specific antibiotic agents for control of tuberculous disease.

In contrast, the employment of the *isonicotinic hydrazides* for orthopaedic lesions has been possible for a mere eight months. Only one year's knowledge of the clinical application of these new antituberculosis chemicals is at hand. It is not surprising, therefore, that, although study has been intense, much knowledge of the benefits, toxity, and results is still of a general nature and, in some respects, is considerably confused. Out of the nebulous multitude of clinical notations, laboratory statistics, roentgenographic studies, the records of physical and psychic reactions of patients, and the diverse assimilations and interpretations of such material by physicians, certain facts only now begin to appear. Much more time must elapse before true recognition of results, both as regards the treatment of tuberculosis with these chemicals and as to their side effects. Despite this, we would release such facts as there may be in order to prevent needless repetition, to avoid certain disasters, and to suggest further lines of investigation. The medical profession itself should be the first recipient of such knowledge; the only way to accomplish this is by the complete spreading upon the medical record of all knowledge at hand.

TREATMENT OF BONE AND JOINT TUBERCULOSIS

The earliest reports embodied in the *Quarterly Bulletin of Sea View Hospital*[1] began the story and are well worthy of review. They were conservative and none of the impressions have been reversed.

* Read at the Joint Meeting of the Orthopaedic Associations, London, July 4, 1952.

Observations of Clinical Benefits (Table I)

Temperature reduction in patients with orthopaedic lesions, with or without sinuses, has continued to be constant. Weight gain is usually very great and occurs consistently; very few patients using the drug have shown no weight gain. Altered sinus drainage has always occurred, particularly with benefit as to the nature of the discharge. Where the discharge has been thick and flocculant, it rapidly becomes serous and less irritating to the surrounding tissues. The amount of the discharge has always decreased, often

TABLE I

BENEFICIAL CLINICAL OBSERVATIONS IN TUBERCULOSIS

Temperature reduction	Universal
Relief of pain	Marked
Weight gain	Great
Altered sinus drainage	Always
Wound healing	Usual
Capillary dilatation	Common
Bacteriostatic action on tubercle bacillus	Amazing

TABLE II

SINUS DRAINAGE
(Character of Drainage Altered and Amount Reduced)

Sinuses healed	20
Sinuses still open	15
Sinus formation prevented	4

spectacularly. Bacteriostatic action as regards the tubercle bacillus has been amazing, constant, and will be specifically recorded hereinafter. Three favorable reactions are of great importance: the dramatic relief of pain, definite evidence of promotion of wound healing, and capillary dilatation or proliferation (granulation tissue).

Relief of Pain

Pain relief has been universal and marked. Within a week or ten days narcotics have universally been discarded if previously used. With the relief of pain, euphoria has gradually developed. After three or four weeks the euphoria has decreased and the patient has been left with a normally optimistic instead of a depressed attitude. Occasionally the euphoria has been of such extent and its effect so prolonged that the patient's state has resembled that of mild narcotism. This indicates the advisability of slow decrease of the drug on withdrawal rather than sudden cessation.

The above observations suggested to us the use of this chemical in conditions other than tuberculosis.

Wound Healing

Wound healing often appears to occur in spite of the bacterial flora. Where sinuses with tuberculosis and mixed infection have been present, even for long periods, we have seen them close in seven to fourteen days. In this period of time, the cultures have indicated that the wounds and surrounding tissues were still contaminated with both tubercle bacillus and mixed-infection organisms. Such rapid and surprising healing does not occur routinely. Since among many of the most startling instances has been closure of deep sinuses, and since the final epithelial coverage is the least of the changes which occur, our feeling has been that these drugs may have a far greater action on tissues of mesodermal origin than on those of ectodermal origin.

Capillary Dilatation and Proliferation

Capillary dilatation or flushing of the skin has been a routine finding. Further evidences of capillary proliferation and dilatation with concomitant promotion of wound healing have been noted in tuberculous soft-tissue abscesses. In a patient who had been under treatment with iproniazid for five weeks, a large thigh abscess was incised, and the wound was sutured. The thigh was compressed with elastic bandaging, postoperatively; on removal of the dressings, the abscess pocket was completely healed and has not since re-formed. At the time of incision, the abscess material, instead of being flocculant, was thin and sanguineous. Sinuses of other patients which have healed have frequently shown a bloody tinge before final closure. In patients under treatment with iproniazid with decreasing sinus discharge, palpation of the abscess often results subsequently in a slightly blood-tinged discharge. The whole phenomenon seems to indicate vigorous granulation-tissue formation, lining of abscess cavities, and eventual adhesion of cavity walls on contact. We have never seen this happen before. These facts seem to indicate another side action which might be employed to advantage in certain non-tuberculous lesions.

Bacteriostatic Action as Regards the Tubercle Bacillus

The question is at present being argued as to whether or not the use of these new chemicals will obviate the necessity of surgery or reduce the amount required. From our experience, surgery will certainly still be necessary. Its use, however, will be greatly reduced as to frequency and extent. We have had a patient with tuberculosis of the spine, adequately fused from the third cervical to the second lumbar vertebra, return three years after discharge with an abscess in the side of the neck and roentgenographic changes typical of tuberculosis in the cervical spine, above the fused area. Following the use of iproniazid and repeated aspiration of the abscess, the mass has disappeared for the present, with complete recession of all clinical signs of cervical-spine involvement. Another patient with proved tuberculosis and with a sinus from the spinous process of the first lumbar vertebra, as well as from the vertebral body and neural arch, gained twenty-six pounds in twenty-five days, and was continued on the drug for an additional month after his sinus had healed. The sinus has remained healed and he has been in excellent condition at full laborious activity for the past six weeks. What the final outcome will be, of course, cannot be determined at this instant. Certainly in both cases, according to our previous concepts, surgery would have been necessary.

Not only will the extent of surgery apparently be reduced, but surgery will be made possible upon certain individuals who would not have been considered suitable surgical risks. In this respect, the results of therapy with these chemicals resemble those from the use of streptomycin. In our opinion, however, the nicotinamides are proving more powerful and more specific than streptomycin. Certain severe complications, such as deafness and dermatitis, arising with the use of streptomycin, have not been encountered with iproniazid. During the past six months no new patients have been placed on streptomycin therapy.

Sinuses have not only been healed, but they have been prevented. Incisional surgery through active tuberculous pockets on five occasions has shown clear evidence of impending wound breakdown. In one instance, the wound breakdown was completed into sinus formation. In that patient the use of iproniazid was delayed for three days; healing is now occurring with this medication. In another patient, sinus formation was anticipated and iproniazid therapy was begun before incisional surgery. In the other three, the red, macerated, moist wounds promptly regressed with the institution of iproniazid therapy.

Among the patients treated by us there have been thirty-five sinuses present (Table II). Twenty of these have healed and to the present have remained healed; fifteen are open or spontaneously re-open and close. Many of those which healed and remained healed reopened and produced spotting on two or three occasions for a few days before final closure.

TABLE III

Sinuses Open		15
Negative to guinea-pig inoculation after 11 weeks of treatment	10	
Guinea pigs lost	2	
Cultures reversed after 4 to 6 weeks of treatment	3	

TABLE IV

CENTRAL NEUROTOXIC SYMPTOMS

Dizziness (slight)	Common
Tremor (mild)	Occasional
Hypertonic reflexes	Usual
Clonus	On high dosage
Euphoria	Frequent
Psychosis (in two patients)	On withdrawal
Cerebrospastic convulsive coma (in one patient)	After prolonged clonus

It is with great hesitancy that we speak, at this time, as to the bacteriostatic action of these chemicals on the *Mycobacterium tuberculosis* as related to the residual open sinuses. Of the fifteen residual open sinuses (Table III), ten were negative to guinea-pig inoculation before eleven weeks of treatment had elapsed and they have remained negative. In three, the cultures were reversed from positive to negative in four to six weeks and have remained negative. The guinea pigs used for the tests of two patients were lost. These findings would seem to indicate that there was complete control of *Mycobacterium tuberculosis* in bone and joint tuberculosis with mixed-infection sinus formation. Such we feel sure is not the case, despite the foregoing observations. We have a premonition that the material does bacteriostatically control tuberculous infection to a great extent, and also that some profound change is occurring in the organism which may cause it to be not demonstrable by previously known cultural methods or guinea-pig inoculation. The theory has been advanced elsewhere that the use of these chemicals causes a change in the tubercle bacillus, which may enable it to survive only at the expense of becoming non-virulent.

Toxic Manifestations

Toxic manifestations noted by us have been due, first, to concentration of the drug in the spinal fluid, and secondly to liver damage.

We have noted as high as 5.2 gammas per milliliter in the spinal fluid. This is a clinically toxic level. Five blood-plasma and spinal-fluid specimens taken simultaneously all show appreciably higher levels of the drug in the spinal fluid. The average level in the blood plasma was 1.48 gammas per milliliter and in the spinal fluid 2.35. The average increase in concentration in the spinal fluid is 58.1 per cent.

Jaundice has been noted in only one patient in this series. After prolonged medication for tuberculosis of the lumbosacral spine with draining sinus, the sinus closed. The patient had persistently had tremor and intermittent clonus; the dosage had been two milligrams of iproniazid per kilogram of body weight. On closure of the sinus in the left lumbar region, complaints of retro-abdominal tension occurred and within a day or so the patient began to become jaundiced. Iproniazid was stopped, but the jaundice progressed. Clinical and laboratory data convinced the medical consultants that the jaundice was of the obstructive type. Convulsive coma of the cerebrospastic type developed with unconsciousness for forty-eight hours. Although there was a history simulating a gall-bladder attack one year previously, and the medical consultants felt that obstructive jaundice was present, surgery

TABLE V

SYMPATHETIC NEUROTOXIC SYMPTOMS

Dryness of the mouth	Common
Diaphoresis	Frequent
Visual-accommodation weakness	Common
Urinary hesitancy	Occasional
Obstipation	Frequent
Impotency (males)	Frequent

was impossible because of the patient's condition, and the only treatment was supportive. After forty-eight hours, recovery began; this has proceeded to essentially complete recovery at present. Despite the confused picture, for the purpose of this record we are crediting this patient with having had a toxic jaundice instead of an obstructive jaundice. Others [2] have reported that in laboratory animals who survive toxic hepatitis from these chemicals, 90 per cent. recovery of liver structure occurs.

Central Neurotoxic Symptoms (Table IV)

Slight dizziness and somnolence are usually experienced on beginning administration of the drug. These tend to decrease and disappear with continuance of medication. Mild tremor occasionally occurs, but disappears unless associated with clonus. Hypertonic reflexes are usually present with satisfactory levels of medication.

Ankle clonus may occur with the usual amounts of medication. The clonus is peculiar. It may be elicited by intention—that is, if the patient is directed to flex the toes slightly, a sustained clonus may be obtained, and it will disappear when the patient is told to relax. It may be present on one examination and absent immediately afterward. With increased toxicity, the clonus becomes present and sustained even without intention. The appearance and development of clonus seems to be the clinical warning sign for reduction of medication. At the present time, it would seem extremely important to watch for clonus frequently while patients are under medication with these chemicals and to reduce the medication promptly on demonstration of the clonus. Then one may gradually increase the medication to a level which permits hypertonic reflexes but avoids clonus. There has been considerable variance in the susceptibility of patients to dosage, as regards the development of clonus. Sustained clonus has occasionally been elicited with patients who continued on as low a dosage as two milligrams per kilogram of body weight. Frequently, however, patients have been continued on dosages of four milligrams per kilogram and

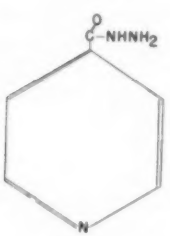
TABLE VI

PRESENT STATUS OF TUBERCULOUS PATIENTS

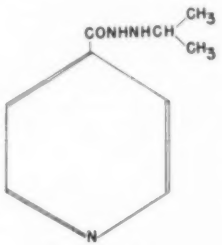
		No. of Patients
Still hospitalized		21
Patients discharged		13
6 have discontinued iproniazid		
7 still on iproniazid		
Iproniazid stopped in	12	
11 have healed sinuses		
1 has persisting sinus		
Patients who have died	2	
1 in 8 days		
1 in 12 weeks		
Total		34

have never shown either hypertonic reflexes or clonus. Euphoria is a frequent finding, as previously stated.

Severe evidences of central neurotoxic symptoms have been presented by three patients, all women. One patient developed a psychosis two weeks after withdrawal of the drug. Since blood-level and spinal-fluid estimation have shown practically complete elimination of iproniazid forty-eight hours after withdrawal, there is some question as to whether this patient's psychosis was related to drug toxicity or was merely an accentuation of a peculiar personality noted before hospitalization. She showed considerable disorientation, excitement, and loss of the usual inhibitions. She had never had tremor, hypertonic reflexes, clonus, or any other sign of central neurotoxic irritation until the sudden development of her psychosis. She is at home, but has not completely recovered psychically. A psychosis with disorientation in a second patient developed while she was on iproniazid. She recovered in six days after withdrawal of the drug. The third patient was the one previously spoken of as having had jaundice. In this woman a cerebrospastic convulsive coma had also developed. This persisted for forty-eight hours with complete recovery, and with only mild residual icterus which is rapidly decreasing. These last two patients with psychosis had had persistent clonus and associated generalized tremor during medication. Clonus had persisted despite reduced amounts of the drug.



FORMULA 1
Isoniazid



FORMULA 2
Iproniazid

Sympathetic Neurotoxic Symptoms (Table V)

Most of the patients developed slight dryness of the mouth at about the end of the first week of medication. Severe diaphoresis occasionally occurred and slight amounts were frequent; this tends to disappear on continuance of medication. Weakness of visual accommodation was frequently complained of; many patients were able to see well both at a distance and closely, but were unable to change suddenly from distance to reading. When present, this weakness in visual accommodation seems to be persistent during medication, but to disappear thereafter. Urinary hesitancy, obstipation, and (in males) impotency were frequent complaints. In some of the patients, impotency disappeared on continued medication at the same level of dosage; in some it was persistent. When medication was removed, impotency disappeared. In only one patient was urinary hesitancy particularly annoying; it was temporary. Obstipation seemed to be not only frequent but persistent; it too disappeared with cessation of the drug.

Present Status of Tuberculous Patients (Table VI)

We have had thirty-four patients under continuous study. The first six patients were placed upon the drug in November 1951, and four of these are still on medication. Gradually this series was expanded. Of the thirty-four patients, twenty-one are still hospitalized; thirteen have been discharged.

Of the discharged patients, six have discontinued iproniazid but seven, as outpatients, are still on the drug. The drug has been stopped in a total of twelve patients, eleven of them with healed sinuses and one with a sinus still persisting. The latter is the patient in whom jaundice developed.

Two patients died, one in eight days before any effect of iproniazid was observed and one in twelve weeks. The latter patient had seven draining tuberculous lesions, lungs

TABLE VII

TUBERCULOUS LESIONS TREATED

Bone	30
Joint	22
Skin	4
Meninges	2
Tendon sheath	2
Fascia	8
Peritoneum	1
Genito-urinary system	1
Total	70

positively infected with tuberculosis, knee-flexion contractures, and pathological dislocation of one hip. He slowly improved for eleven weeks and then rapidly deteriorated, apparently having lost control of the blood proteins and electrolyte balance.

In all of the patients placed on these drugs, the condition was serious, and in most of them it was desperate. Twenty-eight of the patients had had streptomycin without benefit. For these patients who do not respond to streptomycin, there is no question that these chemicals present great possibilities.

Isonicotinic Acid Hydrazine versus Isonicotinyl-Isopropylhydrazine

Isonicotinic acid hydrazine (Formula 1) is the common chemical currently released in the United States for use by physicians under the Food and Drug Administration. Isonicotinyl-isopropylhydrazine (Formula 2) is a "product" not yet released for general use. On two patients isoniazid (isonicotinic acid hydrazine) was used for six weeks with but little change in drainage or sinus formation. Then without word to the patients iproniazid (isonicotinyl-isopropylhydrazine)* was substituted. Within four weeks the sinus had healed in one patient and it has remained healed, and in the other patient the drainage was reduced by 50 per cent. Both patients noted one week after the substitution of iproniazid that a considerable change was occurring and voluntarily remarked upon it. Others studying these two products have noted the same comparable effects. Neurotoxic symptoms appear to be greater with iproniazid.

Dosage of Isonicotinyl-Isopropylhydrazine (Iproniazid)

From our observations, we believe that this drug should be begun at four milligrams per kilogram of body weight. If this dosage can be continued without development of clonus, satisfactory levels for bacteriostatic action as regards the tubercle bacillus seem to be established. As has been stated, the clinical indication of the level of toxicity seems to be the development of clonus. With the development of clonus, the drug should be reduced to two milligrams per kilogram or lower. Thereafter it can be advanced gradually from day to day until clonus reappears, and then reduced so that hypertonic reflexes may persist, but without clonus.

Tuberculous Lesions Treated (Table VII)

Among the patients treated there have been thirty lesions of bone, twenty-two of joints, four of skin, two with meningitis, two with tendon-sheath infection, eight with fascial lesions, one with peritonitis, and one with a genito-urinary lesion.

The lesions of the skin, of the meninges, and of the peritoneum were included in our study and were treated with iproniazid because of the disastrous implications present.

* The iproniazid used was furnished for this research by Hoffmann-La Roche, Inc., to whom grateful acknowledgment is made.

We have watched these patients closely. The fascial and genito-urinary lesions occurred in patients with tuberculosis of the bone or joint; the tendon-sheath lesions were solitary infections.

The response of patients with tuberculous bone and joint involvement has been excellent. In one patient with a tendon-sheath lesion, the lesion has healed; he is not taking the drug and is at work. The other patient with a tendon-sheath lesion, still on medication, is improving steadily. The four lupus vulgarus lesions are healed and the patient is no longer on medication. Both patients with tuberculous meningitis have recovered, although for the present they are still being continued on iproniazid therapy. One, an adult, is normal; the other, a baby, has some hydrocephalus. The patient with peritonitis has recovered and is not now taking medication. All fascial lesions responded rapidly and well. The genito-urinary lesion has healed, as shown by bacteriological study, but the patient still has considerable bladder sensitivity with urgency, frequency, and dysuria.

Laboratory Tests Done

Laboratory studies included 17-ketosteroids, urine analyses, blood counts, platelet counts, blood-protein tests, albumin-globulin ratio, acid phosphatase, alkaline phosphatase, blood calcium, and phosphorus determinations, and sedimentation rate. Repeated checks of all of the above tests were done on this series of patients. Results have shown no change related to the drug therapy.

Liver-function tests with bromosulphathalein and the cephalin-flocculation test were done before medication was started on each patient and at first were repeated weekly. Recently these tests have been performed only at monthly intervals. They have consistently been negative, except for the one patient previously mentioned in whom jaundice developed with cerebrospastic convulsive coma. Even her liver-function tests were negative until closure of her sinus; complaint had developed of a feeling of retroperitoneal tightness with the onset of jaundice and cessation of iproniazid therapy. We cannot help referring to her again, having in mind the question of obstructive rather than toxic jaundice. With beginning of recovery, her sinus re-opened, there was slight spotting, and she was relieved of her retroperitoneal-pressure symptoms. Her sinus has closed for a day or two since recovery occurred, and each time she has again complained of a sense of retroperitoneal tightness. Obstruction could be occurring in her common duct from retroperitoneal retention of tuberculous detritus with closure of her sinus.

Roentgenographic Changes

Despite laboratory findings of apparently normal bone metabolism, certain roentgenographic changes appear to occur with regularity on prolonged use of this chemical.

Generalized osseous decalcification appears to occur after nine to twelve weeks' medication. Whether this decalcification is actual or not, it appears so routinely that it cannot be disregarded. The problem arises as to whether it is due to increased bone vascularity, fat substitution, fibrosis, or masking of bone structure by weight gain. The cortex seems to become thinner and atrophic; the cancellous structures appear atrophied and much less dense. Union of surgical ankyloses seems to be hastened.

No other great changes have become apparent and considerable further time and investigation will be necessary before any positive statements can be made about the changes observed.

SUGGESTED FURTHER INVESTIGATION

Suggested Laboratory Investigation

From the clinical picture presented, we have already raised the question as to whether this chemical has a selective side action on tissues of mesodermal origin out of proportion to that on other structures. It would, therefore, seem wise to suggest that tissue-culture

studies be made, particularly on tissues of mesodermal origin. The influences on the development of the fibroblasts and notation as to changes in old fibrous tissue, if demonstrable in tissue culture, might be of extreme importance.

We are dissatisfied with the check we have made as to 17-ketosteroid levels; and we are already doing further investigative work on this. Blood studies as to circulating eosinophils have been done on patients who have been long under medication; these have been normal. Such studies will need to be continued on new patients as they are put on medication. Nitrogen-balance studies must also be done on these patients. Such studies are an indication as to whether or not these chemicals do actually stimulate the patient's own cortisone formation, as suggested elsewhere. In view of the wound healing, the negative 17-ketosteroids, and the negative circulating eosinophil estimation, we feel that no such stimulation exists

Blood-volume studies and determinations of sodium and potassium electrolyte balance are indicated in an effort to assess accurately the relationship of the considerable weight gain exhibited to bodily structure or fluid retention. To date, the indications are that the weight gain is basic and not in any sense due to fluid retention.

Calcium and phosphorus metabolism studies and studies of vitamin-D absorption and activity are essential, in view of the apparent generalized bone atrophy occurring with no present laboratory indication of bone-metabolism change.

Studies of trephine sternal biopsy with bone marrow and bony structure might aid in determining the deciding cause of the apparent bone atrophy seen in the roentgenograms.

Problems Developing from Roentgenographic Changes

The apparent bone atrophy and changes in the cortex and cancellous structures indicate possible profound effects from the use of this material, which might be controllable and useful in non-union of fractures, bone-grafting, and arthrodesing procedures.

USES OF IPRONIAZID IN NON-TUBERCULOUS LESIONS

From our observation of changes occurring with the use of this chemical in patients with bone or joint tuberculosis, certain side reactions were noted:

First, among these patients there were lesions co-existing and of non-tuberculous nature. Certain of these showed considerable change, and for this reason we have attempted to reproduce this change in patients with similar lesions and without tuberculosis.

Secondly, tremendous relief from pain was noted among the tuberculous patients and we have attempted to reproduce this relief of pain in other non-tuberculous patients.

Third, there seemed to be considerable evidence of an influence toward wound healing of mesodermal tissues out of proportion to any influence of the chemical on the tubercle organism alone.

Non-Tuberculous Lesions Treated with Iproniazid

A patient with tuberculosis of the spine had draining sinuses opening over the trochanteric region. She also had a lupus erythematosus, non-tuberculous in nature, with severe facial changes. She was treated with iproniazid for the tuberculosis of the spine and mixed-infection sinuses; these rapidly responded. The lupus erythematosus to our surprise also responded and healed; it has remained healed to the present. In view of the improvement of this patient, two other biopsy-proved cases of lupus erythematosus were selected by a dermatologist, and these patients were treated with iproniazid by us. They are included in this study. Both appear to be showing essentially the same improvement and changes as the first patient.

A patient treated for a tuberculous knee had severe fibrotic flexion contractures of the fingers and rigid claw hands. Marked release of the fibrotic changes and flexion contractures and marked improvement of the hands were noted after six weeks of treatment;

this improvement has continued. As in the other patients in this series, no other medication than iproniazid has been employed.

As to wound healing, two patients with infected compound fractures were placed on the drug. One had had a pathological fracture with reactivation of localized osteomyelitis two years after the injury. On treatment with aureomycin and penicillin, healing was secured. Through a separate incision iliac strip-grafting had been done. Immediate severe reactivation of the infection occurred which was uncontrollable by the antibiotics previously used, the organisms having become resistant. Under iproniazid therapy, the discharge rapidly changed in character and over a period of six weeks subsided to the status of a dry crusting wound. The surrounding enlarged, boggy soft-tissue mass also rapidly resolved to essentially normal tissues. Roentgenograms at three months seemed to show union, with the usual marked bone decalcification apparent in patients on prolonged use of this drug. The patient was maintained in plaster, but decalcification present was excessive for this method of treatment. Iproniazid was stopped and drainage recurred, but again receded on re-instituting iproniazid treatment and the patient's sinus now has a dry crust only.

The second patient had sustained a compound fracture of the tibia ten months previously, which failed to unite and the wound continued to drain copiously. Marked surrounding engorgement, discoloration, and enlargement of tissues were present. On iproniazid therapy, the drainage has become markedly reduced, and the thickening of tissues and discoloration are steadily receding. Only three weeks of therapy have been possible to date. Aureomycin, terramycin, and penicillin had been previously given without effect.

Two patients with long-standing chronic osteomyelitis, whose lesions had drained continuously for more than eighteen years, but without evident sequestra, were placed on iproniazid therapy. They have been on the drug for six weeks. In one, a sixty-year-old colored male, there has been but little change. In the other, a white male, thirty-five years old, the discharge has lessened and the soft-tissue induration has receded. No final conclusions are possible at this time. We hope by prolonged therapy to produce decalcification of these sclerotic bones, indicative of increased revascularization. This may prove beneficial as regards combating the infectious process. With increased decalcification of the sclerosed viable bone, hidden sequestra may become demonstrable.

One patient with destructive neoplasm of the right pelvis, extensive in amount, was placed on iproniazid for the relief of pain. He had been receiving 200 milligrams of demerol every three hours for three months, and was demanding more. His condition was rapidly deteriorating. The femoral head presenting through the totally destroyed acetabulum and iliac wall caused him agony day and night. Iproniazid was instituted for the pain, and the pain alone, with no thought of effect on the tumor lesion. On the fifth day, he requested one hypodermic of demerol. Following that, he has had no further demerol or narcotic medication during the past six weeks. He has shown remarkable weight gain and remarkable diminution of the external clinical size of the pelvis and upper portion of the thigh. He is able to actively flex the hip to 150 degrees and to extend it to 180 degrees, to adduct 20 degrees and to abduct 20 degrees, and to rotate it almost fully, despite the fact that the femoral head lies in a mass of tumor. Roentgenograms seem to show progressive destruction of the ilium, despite the clinical decrease in the size of the soft tissues. This lesion was biopsied on two occasions before the iproniazid treatment was begun, but because of severe bleeding inadequate tissue was secured. Another biopsy was done on June 16, 1952, and the pathological report was "hypernephroma". This again emphasizes the possible side effect of this chemical on tissues of mesodermal origin. Much further investigation, of course, is necessary. In any case, pain was relieved.

Because of importunities of confreres not to be denied, and despite our judgment that relief of pain could justly be expected only in lesions of mesodermal origin, iproniazid was used in two cases of proved carcinoma for relief of pain as a substitute for narcotics.

In both instances its use was without any great effect, aside from the usual development of a slight euphoria. In one instance, a patient with a so-called Boeck's sarcoid (diagnosed by exclusion only) was provided with iproniazid under the care of a medical confrere. It was without effect. This patient whose chest appeared massively fibrotic (proved non-tuberculous) actually became worse symptomatically.

Suggested Further Non-Tuberculous Clinical Investigation

It may be that fibrous dysplasias of mesodermal tissue will respond to this chemical. It must be noted that the chemical carries with it certain dangers of toxicity. Where severe contractures, severe adhesions, or other similar lesions exist, we would feel that it is justifiable to investigate such cases, and to use medication by this drug.

For relief of pain we would expect this material to provide considerable benefit in lesions of tissues of mesodermal origin, with inflammatory changes and, possibly, with neoplastic changes. We are by no means optimistic as to any specific influence of iproniazid on the neoplasm itself. May we be definite in stating, in this connection, investigation should only consider the situation as to relief of pain and production of euphoria.

In view of the serious implications of certain peripheral vascular defects and their association, not only with decreased blood supply, but with fibrosis, it would seem justifiable to see if such processes could be reversed in view of the noted capillary changes and apparent influence of the nicotinamides on fibrous tissue. Such a trial may well prove disappointing, but logical deductions would seem to indicate that the attempt should be made and the results should be studied.

ANAESTHESIA ON PATIENTS UNDER TREATMENT WITH NICOTINAMIDES

There has been a report that disasters have occurred from anaesthesia and from associated surgery among patients receiving iproniazid therapy. We have operated upon eight patients fully under the influence of medication with iproniazid; the anaesthetic agents have been sodium pentothal (six cases) and cyclopropane (two cases). There have been no complications noted, referable either to surgery or anaesthesia.

Relief of postoperative pain has been noteworthy.

CONCLUSIONS

1. We are convinced that iproniazid is a great addition to our armamentarium for the treatment of tuberculosis.

2. This chemical has a marked effect on tissues aside from its bacteriostatic control of the *Mycobacterium tuberculosis*.

NOTE: We wish to give credit to Dr. Hudson Wilson and Dr. John Crane Hoover for their assistance in the management of these cases and the gathering of laboratory data and clinical statistics.

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DISCUSSION

DR. ALAN DEFOREST SMITH, NEW YORK, N. Y.: My own experience with the hydrazids of nicotinic acid has been too limited to permit me to say anything about this subject from this standpoint. Dr. Bosworth has given me the opportunity to go over his cases in detail, however, and I have been much impressed by the results. Sea View Hospital, where most of these cases were treated, is a municipal hospital for tuberculosis to which the worst cases in New York City ultimately find their way. Dr. Bosworth and his associates selected the most unfavorable cases on their Service upon whom to try the new drug. The majority were patients who had failed to respond to all the accepted methods of treatment including both streptomycin and surgery. This was, then, a very rigorous test.

(Continued on page 810)

DIGIT TRANSFER BY NEUROVASCULAR PEDICLE*

BY STERLING BUNNELL, M.D., SAN FRANCISCO, CALIFORNIA

Although transferring a digit with a neurovascular pedicle without any skin is a new method, the use of a vascular pedicle is old. The latter method was described by Gersuny in 1887. Esser in 1917 called it an island flap. It has been used many times since, and often by passing the flap to be grafted and the vascular pedicle beneath the intervening skin to the new site.

The method may be used in transferring either end of a digit to the stump of another, or in transferring any finger to act as a thumb. Often part of the index finger has been destroyed with the thumb, so that the remaining portion of this finger may well be spared for the transfer. If, however, the volar digital nerves or vessels of the index finger have been injured, the long finger can be transferred with its neurovascular pedicle and the index finger may be jogged over at the base of its metacarpal onto that of the long finger to act as the long finger, narrow the hand, and provide a good wide thumb cleft.

Wherever possible, all tendons of the transferred digit should be carried over with the digit, to be shortened if necessary, and to receive the stumps of the thumb tendons for reinforcement, thus furnishing motion as well as sensation.

A transferred digit, especially if it is to act as a thumb, should have sensation and

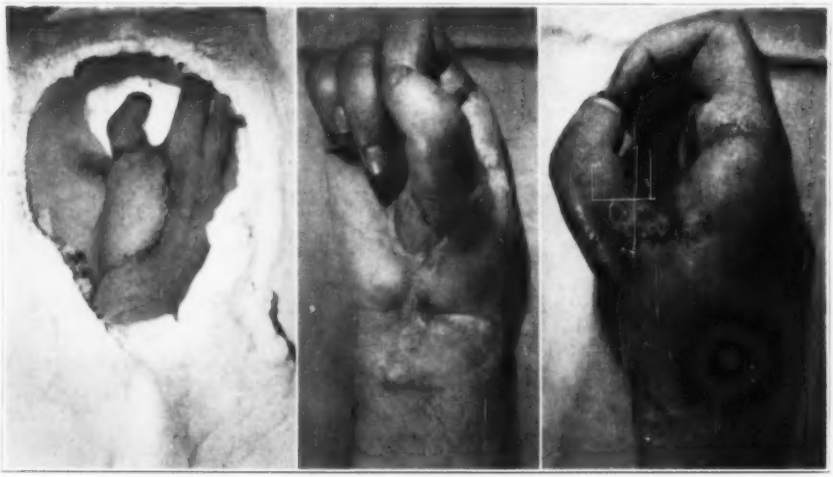

FIG. 1 FIG. 2-A FIG. 2-B

Case R. W. The thumb and adjoining part of the dorsum of the hand were lost by gun-shot wound and a pedicle skin flap was applied to the hand. The index finger had been amputated through its distal joint and the thumb through the base of its metacarpal.

On October 10, 1951, at Letterman General Hospital, the index finger was pollicized. The skin at its base was completely circumscribed. The two volar digital vessels and nerves were exposed and preserved, and these were used as a neurovascular pedicle by which this finger was transferred to act as the thumb. The nerve to the second digital cleft was split back to the base of the palm and the vessel to the long finger was cut and tied, to preserve the blood supply of the index finger. The distal part of the metacarpal of the index finger was thrust into the base of the metacarpal of the thumb and held by one Kirschner wire. The long extensor tendon was preserved but shortened and rejoined.

Fig. 1: Condition of hand on admission to Hospital. Figs. 2-A and 2-B: Condition after operation.

* Presented at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 25, 1952.

FIG. 3

FIG. 4

Fig. 3: Roentgenogram made before operation.
Fig. 4: Roentgenogram made after operation. The metacarpal of the index finger has been arthrodesed to that of the thumb, the index finger having been pollicized.

motion. I have urged this ever since constructing such a thumb by pollicization in 1928.[1] Thumbs made of abdominal skin have not the stereognostic ability of those made from normal skin of the volar surface of the hand which contains special touch corpuscles and which is still connected with its normal nerve supply.

Pollicizing a finger, that is transferring it to the thumb site to act as a thumb, may sometimes be done in one operation, but usually requires several plastic procedures and often the use of a pedicle skin graft as well.

The use of a neurovascular pedicle is presented as a practical method of transferring a digit. In this method a connecting skin pedicle or ribbon of skin is unnecessary and there is much greater facility in placing the transferred digit in one operation.

In 1948, before attempting this with a digit, we "filleted" or "boned" a useless index finger and transferred its opened-out skin on its neurovascular pedicle to cover a bare thumb cleft and part of the palm. To our dismay, one of the volar digital arteries was found to be interrupted, but the other fortunately furnished sufficient vascular supply for the whole transplant to live.

Encouraged by this, we transferred, in the case illustrated, a whole index finger to the metacarpal stump of the missing thumb, completely circumscribing the finger and transferring it on its neurovascular pedicle only. The pedicle consisted of two volar

digital nerves and vessels. The nerve to the second interdigital cleft was split to the base of the palm, so that each branch of the nerve was preserved. At this cleft the arterial branch to the long finger was tied off. The distal third of the metacarpal of the index finger was pinned by Kirschner wires to the stump of that of the thumb.

The transferred digit lived well; it had good circulation and normal sensation. Later its flexor tendon will be connected to furnish motion.

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FRACTURES OF THE CARPAL NAVICULAR *

BY CARRUTH J. WAGNER, M.D., STATEN ISLAND, NEW YORK

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Over the years, a great deal of progress has been made in the treatment of the fractured carpal navicular. With early recognition, reduction of displacement, and uninterrupted immobilization of the wrist in dorsiflexion, union will almost invariably occur in a reasonable length of time with little or no permanent disability [13, 14]. The treatment of the fractured navicular diagnosed late and that complicated by aseptic necrosis of the proximal fragment still remains a difficult problem, however [7]. The traumatologist has a wide selection of procedures to choose from; this reflects the difficulties encountered in solving the problem.

The purpose of this paper is to present the results of treatment of the complication of aseptic necrosis of the proximal fragment; the paper is based upon follow-up studies of thirty-seven cases. All occurred in patients who received initial treatment for their fracture at our institution and amounted to 22 per cent. of a total of 168 fractured carpal navicular treated. Excluded from the report are patients who had received initial care elsewhere, patients referred late for continued treatment, and patients in whom the diagnosis had been missed and arthritic changes had already become apparent. All cases represent fractures of the waist or of the proximal pole of the navicular. The diagnosis of aseptic necrosis was based upon the roentgenographic evidence of failure of the proximal fragment to de-ossify with immobilization. In all cases in which the fragment was removed, the diagnosis was confirmed by pathological examination. Also excluded from this group are three cases in which avascular necrosis had been initiated by multiple drilling for delayed union in fractures at the waist and in which the blood supply to the proximal fragment had been adequate before operation, as well as two cases of a similar complication resulting from bone-grafting in established non-union.

* Read at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 25, 1952.

The three methods used in this study were:

1. Prolonged immobilization 14 cases
2. Removal of the avascular fragment 18 cases
3. Removal of the entire navicular 5 cases

FIG. 1

Prolonged Immobilization

It has been demonstrated repeatedly that prolonged immobilization of the fractured

FIG. 2

Fig. 1: Case 4 (Series A, Table I). Showing the end result of treatment by prolonged immobilization. Note that union has occurred, but the proximal fragment has collapsed because of premature mobilization of the wrist. Immobilization must be continued until revascularization is complete, which usually occurs several months after solid union at the fracture site.

Fig. 2: Case 1 (Series A, Table I). Roentgenogram made six weeks after a fracture of proximal portion of the navicular waist. There was aseptic necrosis of the proximal fragment and extension of the process into the distal fragment, but the fracture site had retained a good blood supply, as evidenced by local decalcification and cystic changes.

It is believed that revascularization will occur in both directions from the fracture site and that surgery in the form of grafting or drilling would inhibit rather than stimulate the process.

Ten months FIG. 3 Seven months

Case 9 (Series A, Table I). Anteroposterior and oblique roentgenograms made after completion of revascularization, at ten and seven months respectively. In spite of prolonged immobilization, disuse atrophy was avoided by extensive exercises.

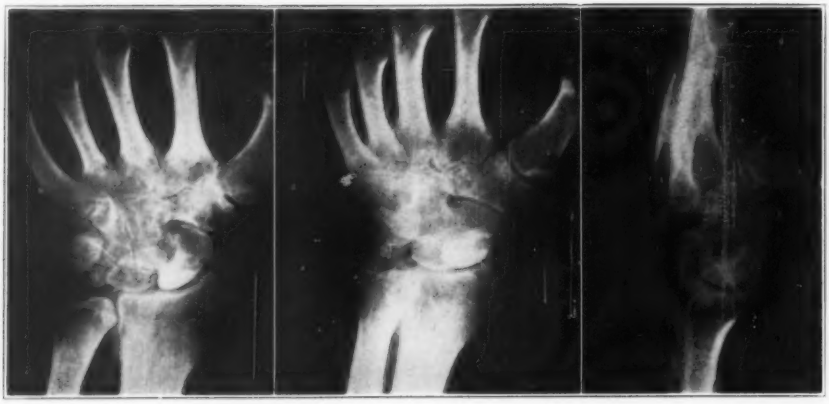

FIG. 4

Case 12 (Series A, Table I). At three months, substitution in the avascular proximal fragment was progressing. The reflex hyperaemic de-ossification suggested more than just a simple fracture of the navicular and study of the lateral roentgenogram revealed disturbed carpal relationship associated with perilunar transnavicular dislocation.

Whenever there is displacement of the fractured navicular, this complication must be suspected and prognosis should be guarded.

FIG. 5-A FIG. 5-B

Fig. 5-A: Although in this case revascularization was complete at seven months, the fracture line remained evident.

Fig. 5-B: At twelve months the fracture was almost healed.

Usually the fracture heals before revascularization is complete. Failure of de-ossification of the proximal fragment at one month does not necessarily indicate aseptic necrosis. In fully half of these cases de-ossification occurred at three months, indicating a temporary inhibition of the blood supply after fracture.

navicular with aseptic necrosis of the proximal fragment will result in creeping substitution in the devascularized fragment and ultimate union [2,15]. It is generally believed, however, that good function does not necessarily result from ultimate union, as the presence of the avascular fragment during the period of substitution inflicts irreversible changes in the articular cartilage of the radius [5,15]. This method of treatment therefore must be carefully studied if it is selected. The prospect of a year or more of immobilization requires a great deal of forbearance on the part of the patient, his employer, and his insurance company. There can be no changing of minds after the immobilization has been begun, as late excision of the proximal fragment, drilling, and bone-grafting in the late stages initiate a disabling

arthritis. Lastly, a poor result and significant disability after long immobilization is a loss not only in the function of the part but in the patient's time as well.

With these facts in mind, it can be pointed out that the fourteen patients treated by this method were not selected. In none was this method of treatment advised; instead, it was forced upon the physician by the patient's demands or by circumstances. Several re-

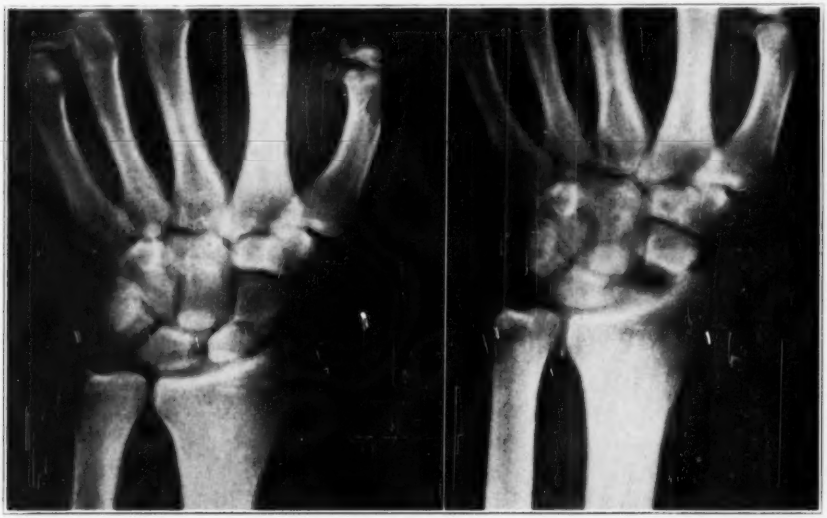

FIG. 6-A FIG. 6-B

Fig. 6-A: Case 1 (Series B, Table II). The roentgenogram shows avascular necrosis of the proximal fragment one month after injury.

Fig. 6-B: Two years after excision of the proximal fragment there had been a shift of the capitate in an attempt to fill the dead space, together with ulnar migration of the semilunar bone. This "carpal rearrangement" is apparently progressive and accounts for late symptoms.

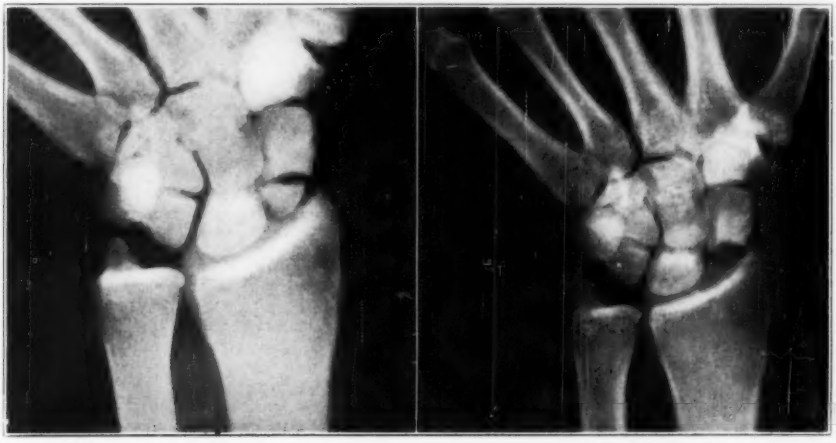

FIG. 7-A FIG. 7-B

Fig. 7-A: Case 17 (Series B, Table II). When the proximal pole is involved, as in this case, removal causes less disturbance in the carpus.

Fig. 7-B: Two and one-half years after resection the relationship between the semilunar, the capitate, and the distal fragment was almost normal. Note absence of traumatic arthritis.

TABLE I

PATIENTS TREATED BY PROLONGED IMMOBILIZATION (SERIES A)

Case	Age	Occupation	Period of Immobilization (*Months*)	Union	Period of Follow-up (*Years*)	Range of Motion	Grip (as Compared with Opposite Hand)	Symptoms	Support
1	22	Carpenter	12	Yes	2.5	Full	Equal	Mild	No
2	18	Postal clerk	11	Yes	5.5	Full	Equal	Absent	No
3	31	Laborer	12	Yes	5	Full	Equal	Mild	No
4	34	Laborer	8	Yes	4	One-half	Equal	Moderate	Yes
5	30	Laborer	16	Yes	3	Full	Equal	Absent	No
6	24	Carpenter	10	Yes	2.5	Full	Equal	Mild	No
7	20	Rigger	8	Yes	2.5	Full	Equal	Mild	No
8	29	Seaman	11	Yes	2	Full	Equal	Absent	No
9	22	Laborer	10	Yes	1	Full	Equal	Absent	No
10	27	Laborer	11	Yes	4.5	Full	Equal	Absent	No
11	20	Clerk	14	Yes	5.5	Full	Equal	Mild	No
12	29	Seaman	12	Yes	4	Full	Equal	Mild	No
13	32	Laborer	14	Yes	5	Full	Equal	Absent	No
14	19	Laborer	7	Yes	3	Full	Equal	Absent	No

TABLE II

PATIENTS TREATED BY EXCISION OF THE PROXIMAL FRAGMENT (SERIES B)

Case	Age	Occupation	Time of Excision (*Weeks*)	Period of Follow-up (*Years*)	Range of Motion	Grip (as Compared with Opposite Hand)	Symptoms	Return to Occupation	With Support
1	19	Laborer	4	2	Full	Equal	Absent	Yes	No
2	22	Seaman	3	1	Limited	Equal	Absent	Yes	No
3	28	Seaman	4	1.5	Full	Equal	Moderate	Yes	Yes
4	31	Seaman	16	2	Limited	Less	Moderate	Yes	Yes
5	46	Postal clerk	4	3	Full	Equal	Absent	Yes	No
6	71	Retired	3	1	Full	Equal	Mild	—	No
7	60	Seaman	5	2	Full	Equal	Absent	Yes	No
8	20	Carpenter	4	1.5	Limited	Less	Moderate	No	No
9	39	Metal worker	4	3	Full	Equal	Mild	Yes	No
10	42	Laborer	6	2	Limited	Equal	Moderate	Yes	Yes
11	44	Coast guard	5	4	Limited	Less	Moderate	No	Yes
12	28	Seaman	4	1.5	Full	Equal	Absent	Yes	No
13	27	Laborer	3	5	Full	Equal	Absent	Yes	No
14	26	Seaman	4	3	Full	Equal	Absent	Yes	No
15	27	Seaman	9	4	Limited	Less	Moderate	Yes	Yes
16	25	Seaman	4	2	Full	Equal	Mild	Yes	No
17	24	Clerk	5	2.5	Full	Equal	Absent	Yes	No
18	36	Carpenter	4	1	Full	Equal	Absent	Yes	No

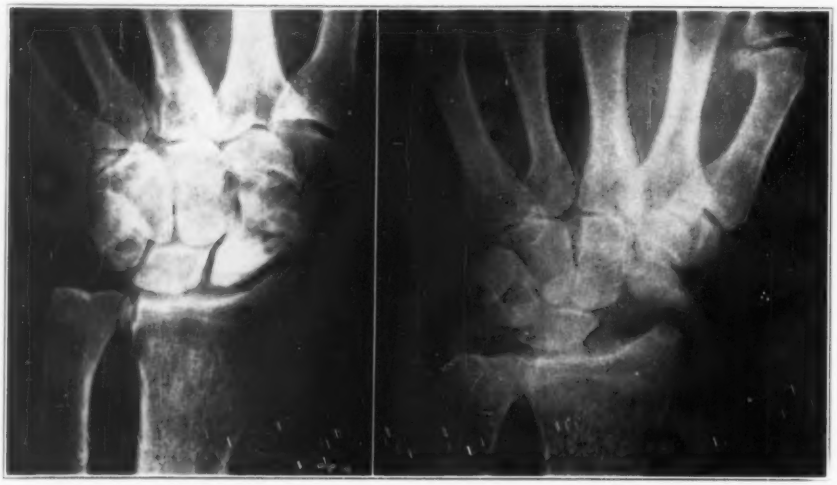

FIG. 8-A

FIG. 8-B

Fig. 8-A: Case 9 (Series B, Table II). When the fracture is high in the waist, removal of the proximal fragment results in early progressive migration of the capitate.

Fig. 8-B: Although the proximal surface of the distal fragment appears irregular, it does not impinge on the styloid of the radius; instead it apparently rotates palmarly on radial deviation, as does the intact navicular. This roentgenogram was made fourteen months after removal of the fragment and tip of the radial styloid.

FIG. 9

Fig. 9: Case 1 (Series C). Roentgenogram made after removal of the entire navicular with subsequent intercarpal fusion. The result was poor in spite of a normal carpal relationship.

fused any form of surgery. Two were minors and could not gain consent of their parents. Several who refused operation were suspected of ulterior motives in regard to compensation.

The results are summarized in Table I (Series A). The average period of immobilization was eleven months; in all cases immobilization consisted of skin-tight plaster from the elbow to and including the hand, with the wrist in dorsiflexion. The thumb to the distal joint was incorporated in a position of opposition, in such a way that it could be just cleared by the index finger in its flexion arc. Use of the hand was encouraged. Casts were changed on an average of every five weeks. In some cases the casts were made of a plastic material and in the others of plaster.

The final results were tabulated after an average follow-up period of three and one-half years. In all cases union occurred and, as may be seen in Table I, the results could be considered good in all but one case.

In this case (Fig. 1) union was secured, but partial collapse of the proximal fragment occurred in spite of immobilization. The shift in the lunate and capitate had not been present originally; it occurred with the collapse of the fragment. Symptoms were becoming

progressively more noticeable and at the last examination it was felt that this man would ultimately require an arthrodesis of the wrist. His course during immobilization had been not unlike that of the other members of the group. The collapse of the proximal fragment was due to release of the wrist before substitution was complete.

Overt arthritic changes in the region of the avascular fragment and radial styloid were observed in only three cases. This would seem to be contrary to the findings of Watson-Jones, but it must be pointed out that the period of follow-up was relatively short and such changes may make their appearance at a much later date.

Mild symptoms consisting of discomfort with weather changes and actual pain on forced extremes of motion with excessively prolonged and heavy work could be elicited in seven (50 per cent.) of these patients, but all had returned to their regular occupation and none required a support while working.

The range of motion and grip as listed in Table I are based on comparison with the opposite extremity. Symptoms were listed as negative when the patient was able to perform his regular occupation without discomfort.

Excision of the Proximal Fragment

There has been a steady trend in the literature [3, 4, 5, 15] toward advocating early removal of the proximal fragment when devascularization is evident. This method of treatment is attractive in that it avoids the prolonged disability attending immobilization and allegedly avoids the traumatic arthritis associated with the other form of treatment. Multiple drilling in an attempt to hasten substitution has fallen into disfavor, but bone-grafting in the presence of aseptic necrosis has strong advocates. Murray, in a series of 100 cases, implanted grafts in thirteen with aseptic necrosis of the proximal fragment and gained union in eleven in an average of four months. It was our custom to advise all patients in whom aseptic necrosis was revealed on the first cast change at four weeks to have the fragment removed. We had several reasons for this advice. The majority of our patients cannot be returned to their regular occupations with an arm in a cast. Union restrictions prevent temporary employment in other fields. It was felt that prolonged immobilization would produce osteosynthesis, but would invariably lead to a degenerative arthritis of the radiocarpal joint.

In this series (Series B) eighteen patients were treated by excision of the proximal fragment. All but two of these were operated upon about four weeks after injury, when the first cast change revealed devitalization of the proximal fragment. Two patients were temporarily without treatment; they had either removed their cast themselves or had it removed and did not return until nine and sixteen weeks later, respectively.

The operative procedure used was simple, a dorsal lateral incision being used. The distal fragment was not disturbed in any case, even though the fracture surface was irregular, as it was felt that the additional trauma and exposure might lead to a traumatic arthritis. If the radial styloid appeared particularly pointed, it was rounded. The wrist was splinted for a week after operation and active exercises were then initiated.

Several occupations are represented in this group. All but three entailed heavy use of the hand. The age group was more advanced than in the first group, but this was not due to selection on our part. The average period of follow-up in this group was 2.2 years. The support used was a molded leather wristlet incorporating a cock-up metal spoon.

As may be readily seen, the end results in this series are not so good as in the group treated by immobilization. Nine (50 per cent.) are now free of symptoms and all but two have returned to their former occupations. On the other hand, in the nine with symptoms, six were rated as having moderate and three as having mild symptoms on moderate use of the wrist; five of this same group also found it necessary to use a wristlet while working.

The roentgenographic appearance of these wrists invariably shows a proximal migration of the capitate with medial shifting of the lunate, apparently in an attempt to obliter-

FIG. 10

CASE 6 (SERIES C). The distal weight of removal of the entire navicular is a rapid migration of the capitate to the radius, shifting of the lunate to the ulnar side, and deviation of the entire hand to the radial side. Intercarpal fusion will prevent the shift but not the deviation.

FIG. 11

CASE 8 (SERIES B, TABLE II). Replacement of the proximal fragment was one-half completed seven months after fracture; union had been complete at five months. Immobilization had to be continued until revascularization was complete, in order to prevent collapse of the proximal fragment, as in Fig. 1.

ate the empty space. This shift occurs shortly after removal of the fragment and soon reaches a maximum. It is perhaps this disturbed relationship which is responsible for symptoms when excessive demands are placed upon the involved wrist.

Excision of the Entire Navicular

Dwyer has reported the end results in nineteen cases in which the treatment of the fractured navicular consisted in early excision of the entire bone. He found that in all early cases the results were good, there was no deviation of the wrist, and stability and motion approached normal. Previously, Hirsch and Davidson had had equally good results with this procedure, but Böhler, Soto-Hall [14], and Aleman had uniformly poor results.

In this series (Series C), five patients had excision of the entire navicular. Two had had comminuted fractures of the navicular with associated radial fractures, one had an avulsion of the tubercle combined with a high waist fracture, and the other two had high waist fractures combined with perilunar dislocation. The periods of follow-up averaged three years; the results were poor. The two patients with perilunar dislocation required arthrodesis of the wrist within a year of the injury. One, a laborer, now requires a brace while working and shows significant weakness of the thumb in gripping. The remaining two have moderate restriction of motion and weakness of grip, but lead sedentary lives not requiring heavy use of the hand. One has a definite radial deviation of the hand which cannot be corrected passively.

DISCUSSION

In comparing the results in these three series, it would appear that the best results are obtained with immobilization until revascularization of the proximal fragment has occurred. The price for somewhat better results is the long period of immobilization and its associated economic inconvenience. When such a method of treatment is unacceptable, fairly satisfactory results can be obtained with excision of the proximal fragment. It must be borne in mind, however, that definite changes occur in the carpus as a result of loss of the proximal fragment. The question whether these changes will lead to significant disabilities later in life cannot be answered by this series, as the follow-up period was relatively short. It would, therefore, appear conservative to reserve this procedure for the older age group and to encourage the young to undergo the prolonged immobilization.

In removal of the proximal fragment it would not seem necessary to round off the distal fragment or to excise the radial styloid. We have never seen a distal fragment impinge upon the styloid; apparently the distal fragment continues to tilt palmarly on radial flexion [9]. It should be emphasized that excision of the devascularized fragment must be done early. With the exception of Murray's report, we can find no evidence in the literature to support the contention that revascularization can be hastened by bone-grafting or drilling. In unskilled hands the end results of such procedures in this complication can be disastrous.

Perhaps our five cases of total excision of the navicular are not sufficiently representative to justify conclusions. Suffice it to say, we are not happy with them and find little indication for such a procedure. It is possible that use of the new spherical prosthesis might produce more satisfactory results.

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DISCUSSION

Dr. James K. Stack, Chicago, Illinois: Dr. Wagner's paper is the most thorough review of a specific lesion of the carpal navicular that I have seen. The basic problem that Dr. Wagner is trying to resolve is how much of the navicular can be removed without endangering the relationship between the remaining fragment and the bones with which it will articulate.

Destot in 1925 published a monograph concerned with his research on the anatomy and function of the carpal bones. He called attention to the fact that the navicular and lunate bones work as a unit, the scapholunar system, and he compared this system to a movable meniscus working around the proximal end of the capitate. This proximal end of the capitate is the common center of the movements of the wrist. It may be described as a kind of rudder which merely tilts as the satellite bones around it describe a varied movement pattern. Since the navicular and the lunate are the only two bones that have a common articulation with both the capitate and the radius, they bear the brunt of movements of the wrist and the brunt of violence directed at the heel of the hand.

Dr. Wagner has not yet seen the long-range results of these cases to determine what the eventual changes would be, but I am sure he feels that certain shifts will take place in the radial carpal alignment which will predispose such a wrist to future trouble. That is my feeling in this matter. I do not believe that any substantial segment of the navicular can be removed without causing the remaining fragment to shift toward the radius, the lunate to shift toward the ulna, and thus to interfere with the combined motion of these two bones. Certainly it has been shown many times that, when the entire navicular is removed, the capitate will press down toward the radius, displacing the lunate toward the ulnar side of the wrist and trapping it there so that it becomes literally a supernumerary bone without function; this sets the stage for the subsequent development of traumatic arthritic changes.

I have had no experience with excision of the proximal pole alone, but have the impression that this is not an entirely innocuous procedure and may not be the answer to non-union and aseptic necrosis of this fragment. I hope that Dr. Wagner will have an opportunity to see these patients after a number of years so that the amount of shift after the excision of the proximal pole can be established.

INTERNAL SPLINT FOR CLOSED AND OPEN TREATMENT OF INJURIES OF THE EXTENSOR TENDON AT THE DISTAL JOINT OF THE FINGER *

BY DONALD R. PRATT, M.D., SAN FRANCISCO, CALIFORNIA

Drop-finger at the distal joint or mallet finger from injury is due to the most common of all tendon ruptures, that of the insertion of the extensor tendon of the finger. This occurs because the extensor apparatus is so much weaker than the flexor tendon that it breaks under strain.

The trauma may be direct or indirect, slight or severe. Direct trauma may be laceration or contusion; indirect trauma is from sudden overflexion of the terminal joint while the extensor mechanism is actively contracted. In some cases, a tiny wedge-shaped fragment of the distal phalanx has pulled off with the tendon; in others, hyperextension, by jamming the nubbin of bone against the dorsum of the middle phalanx, is the mechanism.

The clinical picture is that of mallet or drop-finger, with pain and swelling about the joint, and partial or complete loss of voluntary extension. There may be hyperextension of the middle joint in an effort to extend the distal one.

ANATOMY

In mallet finger the dorsal ligamentous structures, in which is incorporated the insertion of the extensor tendon, are ruptured. In the treatment, we must have a clear conception of the complicated dorsal aponeurosis of a finger. It is obvious that the terminal joint must be held in full hyperextension, but it is less well recognized that the middle joint must be held in flexion in order to overcome the retraction of the extensor apparatus.

Dissected anatomical specimens by Bunnell and others have further developed Hauck's view on the integral parts of the extensor aponeurosis. Anatomically the part of this extensor apparatus over the distal joint can be regarded as the fused lateral slips of the tendons of the intrinsic muscles,—namely, interosseous and lumbrical. The long extensor tendon, the central slip of which attaches to the proximal lip of the middle phalanx, sends interlacing lateral tendon fibers that, together with tendon fibers from the intrinsic muscles, form the lateral bands of the dorsal aponeurosis over the phalanges and insert on the distal phalanx.

The intrinsic muscles flex the proximal finger joint unless the long extensor tendon stabilizes that joint in the extended position. Only then can the intrinsic muscles exert maximum pull on the lateral bands to extend the distal two joints of the finger. As the proximal joint is flexed past 45 degrees, the effect of these intrinsic muscles becomes less, and maximum action of the long extensor tendon on the distal two joints of the finger occurs. The volar shift of the two lateral bands at the middle joint is important. These, which at the middle joint are in a rather dorsal position, shift volarward one-fourth of the thickness of the finger, as the joint is flexed, so as to short-cut this joint. This volar shift is important in the repair of the insertion, since it yields three millimeters of slack in the tendon. The entire extensor apparatus has an amplitude of only eight or nine millimeters to extend both the middle and distal joints.

THE PROBLEM

The problem is one of restoring the continuity of the extensor apparatus at the distal joint of the finger. Complete recovery is possible only if the end of the retracted tendon is accurately approximated to the raw area of bone on the terminal phalanx. The extensor

* Presented at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 26, 1951.

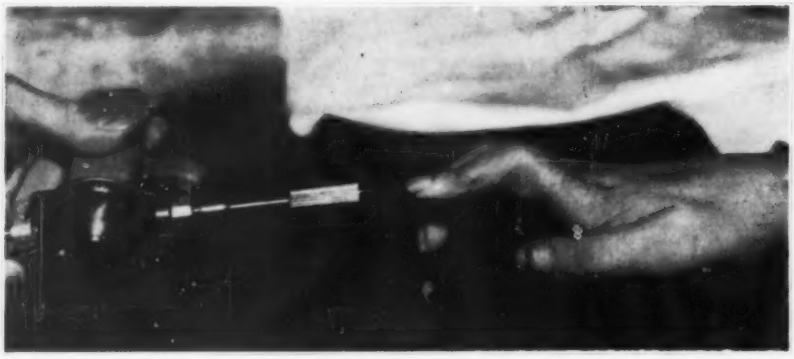

FIG. 1

Positioning of the finger and insertion of the splint.

tendon here, not being in a sheath, will heal well if its ends are together. This is accomplished by hyperextension of the distal joint and flexion of the middle joint. If splinting of the finger in this position is started within a week after the injury and is maintained for five weeks, function will be preserved. If the treatment is instituted after a week or two from the injury or if the position is unsatisfactorily maintained, the tendon will heal in a lengthened condition, thus necessitating surgery.

METHODS OF SPLINTING

Many methods of fixation in the treatment of drop-finger have been described. Merely placing the finger on a tongue blade or using a straight splint turned up at the end to hyperextend the distal joint presents no technical difficulty, but it is obviously inadequate. It has been shown that the middle joint must be held in flexion. In accomplishing this, one encounters mechanical difficulties. Numerous splints of padded wood, malleable metal, celluloid, collodion, plastic, and "celastic" have been described and used. The plastic splint devised by Godfrey[2] maintains the position efficiently.

Very few of these splints actually hold the finger in the desired position; plaster-of-Paris is more effective and is widely used. However, the application of a plaster splint or cast which will effectively immobilize a mallet finger in the required position is surprisingly difficult. Many techniques have been recommended. Watson-Jones describes the use of cellona plaster, with the surgeon holding the injured finger in both hands. Smillie has the patient himself hold the injured finger, wrapped in a sheath of plaster in the desired position, against the tip of the thumb. A method of suspending the tip of the injured finger with adhesive, permitting the application of the plaster on an unencumbered finger, has been described by Williams. Howie advocates applying the plaster to each joint separately and then combining them. Bunnell applies the plaster in narrow wet strips on the volar aspect of the finger, adding dorsal transverse bands as a skeleton splint, open for inspection.

There are many objectionable features in the customary methods of splinting for drop-finger. None of the wooden or metal splints maintain perfect immobility. There is always the possibility of some displacement. Mechanical appliances are clumsy in some degree and tend to disable the hand completely or in part during their use. Splints may occasionally cause local areas of pressure, and they can be removed by the patient if he feels discomfort. Changing the splint to clean it or to wash the fingers permits the possibility of even momentary flexion of the distal joint. Although plaster-of-Paris affords more complete immobilization, it is difficult to apply a cast that will maintain the desired position; there is the danger of external pressure and of interference with circulation.

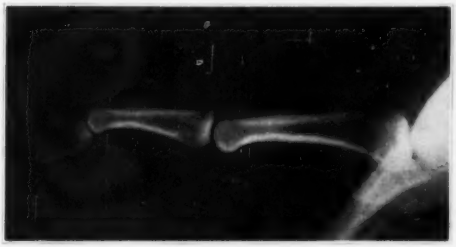

FIG. 2-A

FIG. 2-B

Fig. 2-A: Drop-finger deformity. Fig. 2-B: Deformity corrected with an internal splint.

FIG. 3

FIG. 4

Fig. 3: The internal splint immobilizing the finger in the desired position.
Fig. 4: Sagittal section showing relation of internal splint to the structures of the finger.

The Internal Splint

The following method is offered, which eliminates the above-mentioned difficulties:

A single stainless-steel Kirschner wire of medium caliber, .045 of an inch, is used as a longitudinal internal splint. This affords absolute immobilization of the middle and distal joints of the finger in the desired positions with optimum relaxation of the extensor apparatus.

A small pistol-handle drill is used. The finger is held with the distal joint in full hyperextension and with the middle joint in 60 degrees of flexion. The assistant must hold the finger stationary. It is best to hold the finger in a plane square with the operator and the drill, thus obviating an oblique pin. The point of the wire is started at the tip of the finger and is inserted longitudinally into the terminus of the distal phalanx. It is aimed toward the center of the dorsum of the proximal segment of the finger. The wire passes through the axis of the distal phalanx and crosses the hyperextended distal joint through its dorsal half, thus avoiding the main articular surface of the middle phalanx. It then penetrates the middle phalanx and, as the middle joint is held in about 60 degrees of flexion, the wire passes entirely volar to the middle joint. If the point of the drill emerges centrally on the dorsum of the middle third of the proximal phalanx, the wire will have missed the flexor tendons and will lie between them and the joint. If the original wire is not in the desired position, it is best to leave it in place, and insert a second wire in the correct position. By leaving the first wire in place, one avoids difficulty with the tiny hole left if the first wire is removed before re-drilling. The position of the finger should not be changed after starting the insertion of the drill, in order that binding of the wire may be avoided. In patients more recently treated, the middle joint of the finger has not been held so acutely

flexed; thereby the pin is brought closer to the volar aspect of the middle joint, and any contact with the flexor tendons in their sheath is obviated. The wire is then withdrawn so its point is just palpable under the skin on the dorsum of the proximal phalanx. The distal end is then cut off just beneath the skin of the finger tip. Thus the wire is completely buried; it can be easily removed from the tip of the finger.

The above procedure can be carried out readily under peripheral nerve-block anaesthesia in the operating room of the hospital as an out-patient case.

RESULTS

This internal-splint method has been used in a series of twelve cases. Complete immobilization in the desired position was obtained in all. Six were for fresh injuries which required immobilization only. Full extension was restored after five weeks of splinting. In the other six cases, the internal-wire splint was used in conjunction with an operative procedure. Useful extension was also restored in all six of these. Only one of the patients complained of any discomfort after the first day. In this case, it was felt that the point of the wire was not cut off sufficiently to permit the skin to cover the end of the wire without tension. In subsequent cases the wire at the tip of the finger has been cut off short enough to be just barely palpable beneath the skin. Also, it is important to cut the end of the wire squarely so that it may be grasped easily with pliers at the time of removal. The hands were not encumbered by a mechanical appliance. Since the wire pin holds two joints immobilized, there was no possibility of migration of the wire. The adjacent fingers were permitted full function and all the fingers were free of dressings and could be washed. The fixation pin did not cause joint damage or the loss of normal joint movement. The middle joints of the immobilized fingers limbered up rapidly and soon regained full motion. No breaking of the wires was encountered. There was no interference with circulation and, in the operative cases, there was no postoperative oedema or pressure necrosis from either a constricting splint or a snug plaster cast. No disturbance or infection was encountered about the wire pins.

NOTE: The author is indebted to Dr. Sterling Bunnell and Dr. L. D. Howard, Jr., for encouragement in developing this method.

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DYNAMIC SPLINTING FOR THE PREVENTION AND CORRECTION OF HAND DEFORMITIES

A Simple and Inexpensive Method*

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Active dynamic splinting for the prevention and correction of deformity in injured hands is a well established surgical principle. The purpose of this paper, therefore, is not to expound further the advantages of dynamic splinting or to enter into great detail about the mechanism of deformity and its correction, but rather to present a simple, inexpensive, and readily available method for constructing appropriate splints.

This method is independent of the services of a bracemaker and will be referred to in this article as the plaster technique for dynamic splinting. The technique is not only particularly applicable in wartime during which large numbers of injured hands pass through small outlying hospitals not equipped with brace shops, but also in the management of hand injuries in smaller community hospitals where brace shops are similarly not available. Unfortunately the condition of some of the men from Korea with hand injuries arriving at this Hand Center has re-affirmed the lessons learned in World War II,—namely, that improper splinting results in serious deformities which often require months of corrective splinting and operative intervention.

In addition to the ease of construction, plaster dynamic splints have certain other important advantages; one of these is their individuality. Skin-tight plaster fits more closely and more accurately than many other types of material. This is of the utmost importance in the hand in which there are a large number of joint surfaces functioning in close synergism. The axes of rotation, and the differences between them, present an extremely individual problem; in health and disease great variations are encountered. When plaster is used, it may be molded to allow for these variations, and the joints and hinges may be adjusted exactly over axes of rotation while the plaster is in the process of setting.

Finally, plaster is light and considerably easier to carry for a long period of time than metal. Strength is not sacrificed if a few basic principles are followed. Patients have used a single splint for as long as eight months without replacement. However, as tightened joint capsules and collateral ligaments begin to relax and atrophy is replaced by the development of muscle tissue, the requirements for a splint will change rapidly. The splint which lasts longer than a few months may become a liability rather than an asset.

GENERAL PRINCIPLES INVOLVING THE CONSTRUCTION OF ALL SPLINTS

Splints should be so constructed that they are easily removed, because dynamic splints alone will not always overcome a deformity. To be most effective, they must usually be accompanied by a sound program of physical therapy which emphasizes active and passive motion by the patient. One of the possible pitfalls in the active dynamic-splinting principle is that the patient (and frequently the doctor) is so impressed with the complex of moving parts and rubber traction that physical therapy is neglected. A dynamic splint will hold the relaxed hand in a position to prevent deformity, will allow for motion, and will exert a generalized constant traction in the right direction; but it cannot completely replace the hours which the patient should spend each day in active and passive motion without the splint.

* Based in part on an exhibit at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 1952. Received for publication October 30, 1951.

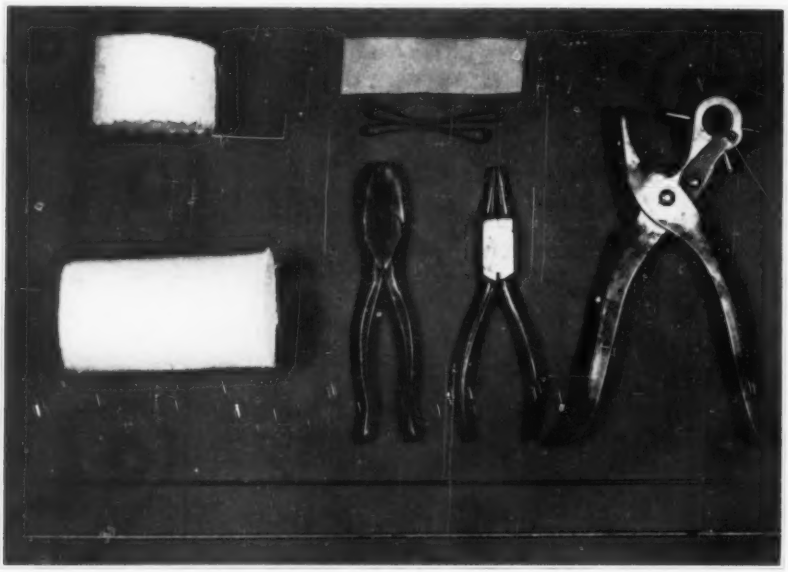

FIG. 1

Materials used in construction of splints. Four-inch and two-inch rolls of quick-drying plaster, pliers, leather stripping, rubber bands, leather punch and eye, and brass welding rods are shown.

A minimum of padding can be used, except at extreme pressure points. A plaster splint molded over the dorsal or volar surface of the forearm and maintained at one end with a metacarpal bar and at the other with an elastic bandage or buckle will not slide in either direction and can be easily removed. This arrangement provides an even distribution of pressure over a large surface area. If a rubber glove can be worn on the patient's hand while the splint is being constructed, the surface of the splint in contact with the skin will be perfectly smooth. No padding is used under such a surface, and pressure sores seldom if ever develop.

Figure 1 shows all of the materials needed to construct these splints.

Plaster

Seven or eight layers of four-inch quick-drying plaster make the best longitudinal splints. The metacarpal bars are made by folding a two-inch strip of plaster on itself so that the center becomes progressively thicker. The thick center section is placed in the palm, the thinner ends overlapping dorsally.

This splint serves as a basis or starting point for all of the corrective attachments. The position of the wrist in this basic splint is the much emphasized but frequently overlooked "position of function"[2]. The wrist joint is the key to this position, as Bunnell has pointed out. With the wrist flexed, which is the position assumed by an injured hand, the long extensors are taut, pulling the metacarpophalangeal joints into hyperextension. If, in addition, there is intrinsic muscle loss, this is further increased because the fingers are then left at the mercy of the long flexors which pull the terminal phalanges into flexion. Extension of the wrist, however, reverses this by relieving the tension on the metacarpophalangeal joints and allowing the fingers to fall forward in a useful position. If the thumb is in direct line with the radius, the wrist is at about the right amount of extension.

The proximity of the axes of rotation in the metacarpophalangeal joints is not gen-

erally appreciated. These axes actually lie between the proximal and distal palmar creases, and one should bear in mind that the plaster must not extend beyond the proximal palmar crease. The distal palmar crease is generally considered as the limit for extension of the plaster, and this is probably acceptable for general immobilization purposes. However, in dynamic splinting, especially where metacarpophalangeal joint flexion is being sought, it is safer to use the proximal crease, as this line is developed through flexion of the metacarpophalangeal joints. It is folly to build complicated traction devices to flex the metacarpophalangeal joints on a basic splint which in itself is blocking flexion at these joints by extending beyond the axes of rotation.

At this point it is well to mention the importance of the transverse metacarpal arch. This arch is maintained principally by the intrinsic muscles and is flattened in many serious hand injuries, particularly when the median and ulnar nerves are involved. During the period of nerve regeneration this arch can be maintained by the volar surface of the metacarpal bar. To accomplish this the patient's thumb is pressed firmly into the center of the bar before the plaster dries, thus molding the volar surface of the splint well into the palm.

Metallic Framework

Hinges, lever arms, and outriggers are made of metal. Brass welding rod has proved to be the most acceptable metal for this purpose. The size most frequently used is three thirty-seconds of an inch in diameter, although occasionally, especially in overcoming wrist deformities, one-eighth of an inch may be necessary. These rods will tolerate more acute bending than copper and inexpensive steel and are easier to handle. Of course stainless steel is the ideal material, but the expense involved is prohibitive and unnecessary. Coat-hanger wire works very well in many instances, but it is not always strong enough to justify its use when brass welding rod can be obtained. Large-size cutting pliers used as a vice and small, pointed-nose electrician's pliers used for making tight loops are necessary in order to handle this material easily.

The wire should change directions within the plaster several times so that it will not rotate in response to a torque placed on its exterior projections. Therefore, it is well to have as many of the exterior projections as possible arise from a single wire running back and forth through the plaster.

Since the greatest point of stress in the splint is at the wire-plaster juncture, these points should be reinforced by applying tiny circular plaster strips around the wire which cross on the splint at this juncture.

Finally, neatness is desirable, especially if the splint must be worn for a long time. Many patients will not tolerate complicated splints if sharp edges, hooks, or excessively long lever arms are left projecting for clothes to catch on. Therefore, all hooks should be completed into loops, ends of wire should turn in, and lever arms should be designed to lie along the longitudinal axes of the splint and to be as short as is mechanically efficient.

Leather

Any soft leather which can be cut into strips and then fastened by metal eyes into loops is acceptable. These loops should fit so snugly that they will not slide along the fingers; but they should be loose enough to be removed easily. Leathercraft sets, which contain a punch and a clamp with which one can apply the eyes, may be obtained at commercial leather stores. In the event of the surgeon's not having access to these materials, cloth or even adhesive tape may be substituted.

Motor Power

Joint deformity is often the result of the unopposed action of a single muscle or muscle group. In order to prevent deformity, the intact muscles must be given an opposing force, thus restoring normal muscle balance around the joint.

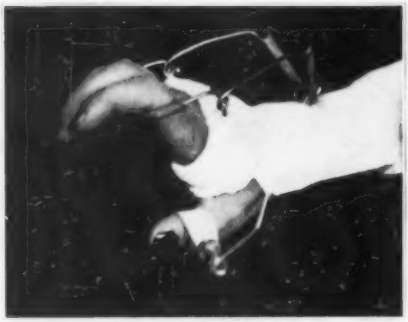

FIG. 2

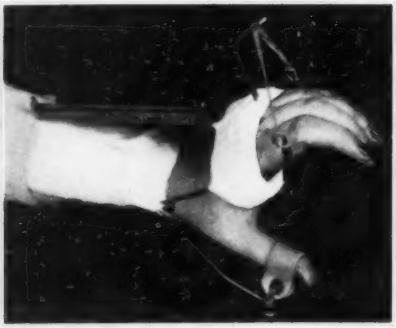

FIG. 3

Fig. 2: *Radial-nerve palsy protective splint.* Rubber bands connect the thumb loop to its abduction outrigger and empower the rider supporting the proximal phalanges.

Fig. 3: *Radial-nerve protective splint,* applying the same principles as the splint shown in Fig. 2. This splint, in addition, has a joint at the axis of rotation of the wrist. The wrist is held in extension by a heavy dorsal rubber band.

Rubber bands provide the most satisfactory substitute for loss of motor power. They are ideal, because tension can be easily adjusted by the patient from day to day without his consulting the physician. They are readily available and offer the least complicated substitute for paralyzed muscles. Occasionally the resilience of metal may be utilized, but this is seldom as dependable or as satisfactory as the elasticity of a rubber band.

SPECIAL POINTS INVOLVING THE CONSTRUCTION OF PARTICULAR SPLINTS

1. *Splints Designed to Protect from Deformity while Awaiting the Return of Peripheral-Nerve Function*

A. *Radial-nerve palsy:* In radial-nerve palsy, the problem is essentially that of keeping the hand out of the so-called "wrist-drop" and protecting the fingers from developing unopposed flexion contractures. In severe, untreated wrist-drop, the long extensor tendons may shorten until the metacarpophalangeal joints become hyperextended. The simple volar "cock-up" splint is the prophylactic splint commonly employed. This method is quite satisfactory if careful supervision of the patient is possible and if he is required to remove the splint daily for active and passive exercises. The two splints pictured in Figures 2 and 3 are designed to hold the wrist in the "cock-up" position, to hold the metacarpophalangeal joint out of acute flexion, to allow a full range of motion in all joints, and to replace the paralyzed extensors with rubber bands. The patient may move the fingers and the wrist if this type of splint is used; thus he may exercise the muscles involved and protect the joints from stiffness. When the patient is relaxed and is not thinking about his deformity, the hand will automatically be pulled into the "cock-up" position by the rubber band on the dorsum of the splint. The only essential difference between the splints in Figure 2 and Figure 3 is that the second splint has a joint at the axis of rotation of the wrist so that the wrist can be exercised also. This splint is probably not necessary because, if a full range of motion in the metacarpophalangeal joint is permitted and these joints are put through their full range of motion frequently, the wrist joint seldom presents a problem of motion limitation. Also, this splint is easily removed, and the wrist joint may be put through its range of motion independently of the splint. Note that a short extension of wire is provided to hold the thumb in abduction. Adduction contracture of the thumb, resulting when the long abductor and short extensor muscles are not acting, can occur largely through the unopposed action of the first dorsal interosseous muscle and the adductor pollicis, which exert far more influence than the abductor pollicis brevis and opponens. The hinges which support the finger rider are directly above the axes of rotation of the metacarpophalangeal joints. This is important to keep the rider from slipping up and

FIG. 4

FIG. 5

Fig. 4: *Index-finger abduction splint.* A rubber band connecting the index-finger leather loop with the wire spreader provides the proper amount of tension.

Fig. 5: *Combination median-nerve and ulnar-nerve palsy protective splint.* The metacarpophalangeal joints are held in flexion of 15 degrees and the volar surface of the splint is molded up into the palm to maintain the transverse metacarpal arch.

down the volar surface of the proximal phalanges. It should be noted also that the rider is curved in two directions: It is arched to conform to the transverse metacarpal arch which is reflected in the proximal row of phalanges; and it is arched in a longitudinal plane to correspond with the shorter length of the proximal phalanx of the fifth finger as contrasted with the proximal phalanx of the long finger. A rubber catheter over this wire is sufficient padding. The metacarpal bar at the distal end of the splint is molded well up into the transverse metacarpal arch and does not extend past the proximal palmar crease.

B. *Median-nerve and ulnar-nerve lesions:* The overlap in nerve supply to the intrinsic muscles is so great that a lesion of either the ulnar nerve or the median nerve alone seldom produces a serious deformity. Occasionally one will see a deviation to the ulnar side of the index finger when the motor branch of the ulnar nerve has been disrupted. A splint such as the one shown in Figure 4 may be used to hold the index finger in proper alignment if a tendon transfer is necessary.

Hyperextension of the fourth and fifth metacarpophalangeal joints can be treated by application of a splint similar to the one in Figure 5. For this purpose the outrigger is connected only to the involved fingers.

The combination of a median-nerve and ulnar-nerve palsy, resulting in the complete loss of power in all the intrinsic muscles, throws the entire muscle balance out of alignment and places all of the joints completely under the influence of the long flexor and extensor tendons. The classical "claw-hand" is the inevitable result, if drastic steps are not taken early in the prevention of this catastrophe. The following developments must be prevented:

1. Hyperextension of the metacarpophalangeal joint;
2. Flexion contractures of the interphalangeal joints;
3. Loss of the transverse metacarpal arch;
4. Adduction contracture of the thumb.

The splint shown in Figure 5 is designed to prevent these four complications from developing. This is the easiest splint of all to construct; yet the failure to apply this splint, or its principles, at an early date may irreparably damage joint relationships and completely alter architecture, thus restricting movement which might have been restored through tendon transfer and arthrodesis at a later date. In this splint the plaster extends as a gauntlet across the top of the metacarpophalangeal joints. It is placed over these joints with the joints in a position of about 15 degrees of flexion, thus preventing them from going into hyperextension. The volar surface of the splint is molded well up into the palm, as previously described, preserving and maintaining the transverse metacarpal arch. A distal

FIG. 6-A

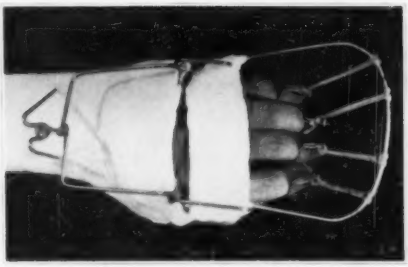

FIG. 6-B

Fig. 6-A: Lateral view of splint designed to flex simultaneously the metacarpophalangeal joints and to extend the interphalangeal joints. Rubber bands, pulling down from between the fourth and third fingers and pulling up on the dorsal lever arm, flex the metacarpophalangeal joints. The finger outrigger is suspended from the plaster base pressing on the proximal phalanges.

Fig. 6-B: Dorsal view of the splint shown in Fig. 6-A.

extension serves as an outrigger from which the motor power given by rubber bands may be suspended, thus providing resistance to the long flexors. A similar extension on the radial side of the splint serves the same purpose in preventing contracture of the paralyzed intrinsic muscles of the thumb. It is extremely important that the splint be removed several times daily in order that all of the joints may be put through their full range of motion.

A hand protected by this splint will present the ideal conditions necessary for the best result in subsequent tendon transfer and joint arthrodesis. Large numbers of these splints were used throughout the hand centers in World War II, and they are now being used with excellent results in the Valley Forge Hand Center.[2] The extreme differences noted between hands protected in this respect and those referred from areas in which no bracemaker was available is one of the main reasons for presenting this method at this particular time.

II. *Splints Designed to Overcome Specific Deformities*

The splints shown in this section are examples of splints designed to overcome specific deformities or to loosen ankylosis of specific joints. There is no limit to the different types of splints which can be improvised for this purpose; each individual case will dictate the requirements for the splint which is necessary to overcome a particular deformity. The splints shown here are only a few of the splints designed to overcome the more common problems encountered.

A. *Knuckle bender for "claw-hand":* One of the most frequently encountered problems is stiff metacarpophalangeal joints in the hyperextended or extended position with stiff distal interphalangeal joints in flexion contractures. Time can be saved if constant traction can be put on both of these joints at the same time, but in a different direction and independent of the tension placed on each. The splint pictured in Figures 6-A and 6-B was designed to accomplish this purpose. The starting point was the usual cock-up splint and metacarpal bar. If the outrigger, which pulls on the finger tips, and the rider, which presses on the proximal phalanges, come from the same base—namely, the dorsal portion of the splint—it is obvious that there would be rubber bands pulling on the fingers in opposite directions. The two "pulls" would approximately neutralize each other, and the resultant force on all of the joints would be insignificant. Therefore, the outrigger from which the finger-tip traction is suspended must ride independently of the base of the splint and must maintain a constant relationship between the tips of the fingers, regardless of what position the rider may assume. In addition to this, greater tension should be applied to the metacarpophalangeal joints than to the distal interphalangeal joints; therefore, there are two rubber bands working on the metacarpophalangeal joint. One rubber band lifts up on the

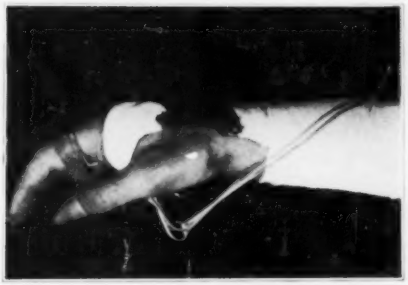

FIG. 7-A

FIG. 7-B

Fig. 7-A: *Wrist flexor.* The leather loops on the fingers are attached to rubber bands suspended from the volar surface of the metacarpal bar. This also produced metacarpophalangeal flexion.

Fig. 7-B: The same patient as shown in Fig. 7-A following removal of the splint six weeks later. A gain of 35 degrees of wrist flexion has been obtained.

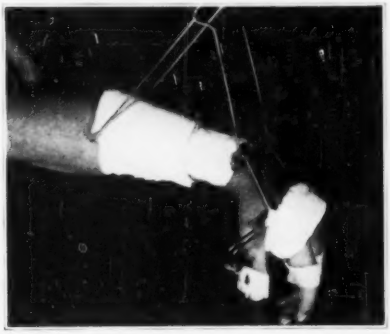

FIG. 8-A

Fig. 8-A: *Splint designed to extend a flexion contracture of the wrist produced by long immobilization in a flexed position.* Suitable outriggers have been provided to abduct the thumb and to flex the metacarpophalangeal joints.

FIG. 8-B

Fig. 8-B: The same patient as shown in Fig. 8-A following removal of the splint four weeks later. A gain of 25 degrees of wrist extension has been obtained.

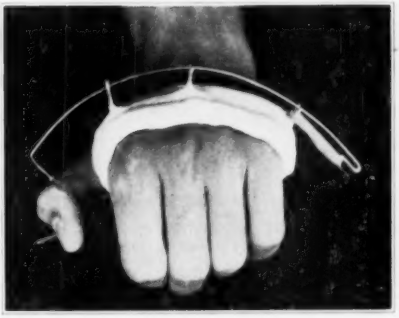

FIG. 9

Fig. 9: *Abduction splint for thumb.* A rubber band between the ulnar metal loop and the abduction lever arm provides motor power.

back of the rider and the other pulls down from a piece of wire between the third and fourth fingers. This gives approximately twice as much pull on the metacarpophalangeal joints as on the distal interphalangeal joints. The greatest pressure area in this splint is beneath the surface of the rider; and, since this must be narrow so as to contact only the proximal phalanges, it is necessary that it be well padded. A felt pad under this area works satisfactorily. If the thumb is also involved in an adduction contracture, a third outrigger can be placed on the side of the splint to pull the thumb into abduction.

B. *Wrist flexors and wrist extensors:* Figure 7-A illustrates an example of a splint designed to flex the wrist. In the particular case shown there was also the problem of providing flexion of the metacarpophalangeal joint. Appropriate outriggers were placed on the metacarpal bar to accomplish this. Overcoming ankylosis of the wrist requires so much more power than does that of the smaller distal joints that one-eighth inch welding rod should be used in making the lever arm for these splints. In the case of the hand shown in Figure 7-A, 35 degrees of flexion was gained in six weeks (Fig. 7-B).

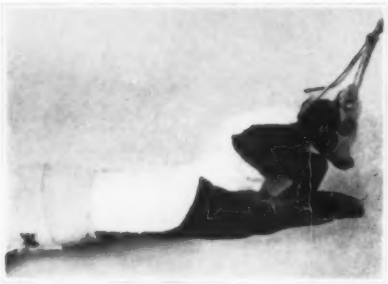

FIG. 10-A

FIG. 10-B

Fig. 10-A: *Splint to extend interphalangeal joints.* The metacarpophalangeal joints are stabilized in 15 degrees of flexion by a felt-padded plaster stop.

Fig. 10-B: Same patient as shown in Fig. 10-A, following removal of splint five weeks later. A gain of 25 degrees of extension has been obtained. The dorsal extensor mechanism over the proximal interphalangeal joints had been button-holed, so that the patient was unable to extend actively the distal phalanges.

Figure 8-A illustrates the same principle, with the exception that the pull is reversed and the splint instead of flexing the wrist now extends it. This patient gained about 25 degrees of extension in four weeks (Fig. 8-B).

In neither of these splints was any padding used. Relatively great tension was placed on the wrist joint by using two large rubber bands; yet, it was well tolerated because of the wide distribution of pressure over a large surface area.

C. *Abduction splints for the thumb:* There have been many types of leather and metal abduction splints designed which are simpler to construct than the one shown in Figure 9. This plaster splint, however, although a little harder to construct, offers the advantage that the continuous arch of the abduction lever over the dorsum of the transverse metacarpal arch places a torque on the thumb which, in addition to abduction, produces a moderate degree of pronation. The splint was made with stainless-steel Kirschner wires. All of the loops which support the abduction lever of the splint should arise from a single wire to protect the loops from motion within the plaster.

D. *Extension of interphalangeal joints:* Flexion contractures of the proximal and distal interphalangeal joints are the inevitable results of neglected and improperly splinted hands. The splint shown in Figure 10-A is one effective way of dealing with individual or collective interphalangeal joint ankylosis. It should be noted that the metacarpophalangeal joints are stabilized at about 10 degrees of flexion and that a felt pad protects the margin of the metacarpal bar at the point where is developed the most pressure against the proximal phalanges. The hand shown in Figure 10-A had gone without proper treatment for so long that it was thought, after both x-ray and clinical examinations, that the joints were permanently ankylosed in this position. However, following the application of the above splint, 25 degrees of extension was obtained in five weeks (Fig. 10-B).

Extension ankylosis can be overcome by reversing the position of the proximal phalangeal stop and metal outrigger.

NOTE: The author would like to express appreciation to Lieutenant Colonel Victor B. Vare, Chief of the Orthopaedic Section, Valley Forge Army Hospital, and to Dr. J. William Littler, Civilian Consultant to the Hand Center, whose pioneer work in this field stimulated the development of this technique.

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PREVENTION OF POSTOPERATIVE HEMATOMA IN SURGERY OF THE HAND

The Use of the "Compression Suture" *

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From the Hitchcock Clinic, Hanover

The success of hand surgery is largely contingent upon the scrupulous avoidance of scar, in the production of which postoperative hematoma plays a significant role. In reviewing those factors in operative technique which minimize the incidence of this complication, two are found to be of outstanding importance—namely, *complete hemostasis* and the *elimination of dead space.*

Hand surgery, usually carried out with the aid of a pneumatic tourniquet, lends itself particularly to accurate hemostasis. Vessels can be identified and ligated cleanly without incorporating extraneous tissue. Persistent bleeding from a fibrous bed may be controlled by electrocoagulation; undue scarring may be avoided by the use of fine iris forceps which grasp the severed vessels individually during the actual coagulation.

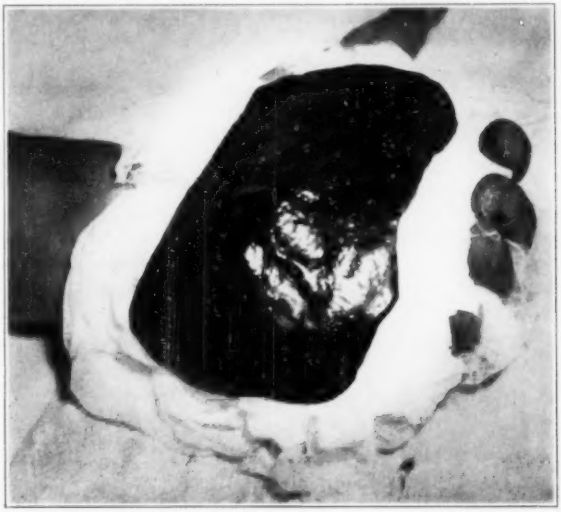

FIG. 1

Impression-compound mold used beneath an elastic bandage for the proper distribution of pressure after the excision of palmar fascia.

Elimination of dead space is equally important, and in most instances can be accomplished simply by an accurate layer closure of the wound. Occasionally the rotation of fat, muscle, or fascial flaps from adjacent areas is necessary in order to eliminate pockets formed either by trauma or by surgical intervention in the soft tissues or in bone. Further security is gained by the use of an evenly distributed bulky dressing of gauze or surgical waste supported by an elastic bandage.

When free grafts are applied to concave contours, where the employment of effective pressure is more difficult, the so-called "bolus technique" is preferable. A series of long-ended sutures is taken through the margins of the grafted defect and tied across a wad of carefully packed fluffed gauze or waste, holding the graft firmly against its bed. Further reinforcement with packing, elastic compression, and a splint should, of course, be used.

Occasionally, however, one encounters situations in which pockets are created which defy conventional methods of eradication. The radical removal of the palmar fascia in the

* Read at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 26, 1952.

treatment of Dupuytren's contracture is notorious for its predisposition to the formation of hematoma. The usual method of applying a pressure dressing with an elastic bandage tends to narrow the hand and to increase its cupping, thus favoring the pocketing of fluid. Another example of this difficulty is encountered in the application of tubed or direct abdominal pedicle flaps to the upper extremity. Such grafts readily adapt themselves to flat or convex surfaces, but significant depressions or recesses in the recipient area present serious mechanical problems in proper application, as well as introducing hazards in maintaining the viability of the flaps. Elastic-bandage pressure of a sufficient degree to press a pedicle flap effectively against the floor of a pocket is necessarily diffuse

FIG. 2-A

Case 1. Defect in the shape of an inverted pyramid remained after the resection of unsuccessfully irradiated squamous epithelioma.

FIG. 2-B

A mattress suture, incorporating buttons on either side, transfixes a covering abdominal pedicle flap and the intermetacarpal space.

FIG. 2-C

Fluffed gauze, placed within the silk loop, is pressed into the defect by tightening the suture, bringing the pedicle flap into effective contact with the underlying base.

in its area of application, bringing overly firm pressure against the portion of the graft overlying the lip of the depression and creating a situation conducive to necrosis.

Several suggestions have been offered in the attempt to minimize the complication of postoperative hematoma. In a discussion of the surgical treatment of Dupuytren's contracture by resection of the palmar fascia, Frackelton mentioned the employment of a dressing constructed like a sandwich in order to obviate the increased cupping of the palm produced by the conventional dressing. Shaw has recently suggested for the same

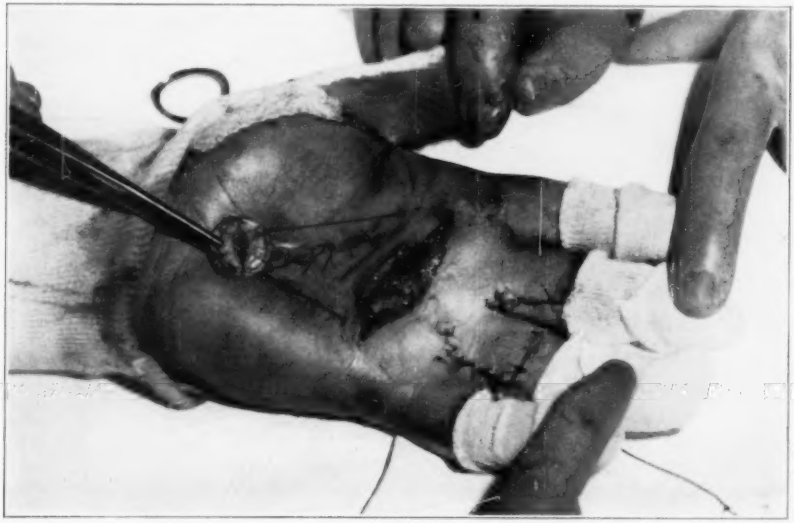

FIG. 3

Use of the "compression suture" following excision of palmar fascia.

purpose the use of a molded plaster splint closely applied to the palm. We have, likewise, used a palmar splint of dental-impression compound (Fig. 1) which is molded over a wad of fluffed gauze and which is then enclosed in an elastic bandage, thus obtaining palmar compression without the undesirable narrowing of the palm.

For the past few years we have employed another type of dressing which we have designated "compression suture" to maintain coaptation between skin pedicle flaps or

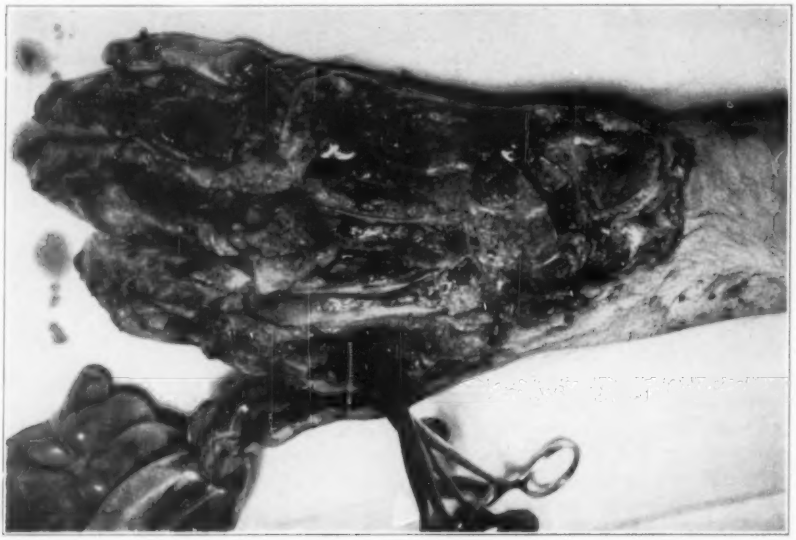

FIG. 4-A

Case 3. Marked destruction of the soft tissues and bones of the dorsal aspect of the hand and wrist resulting from contact with a heavy-duty buffing machine.

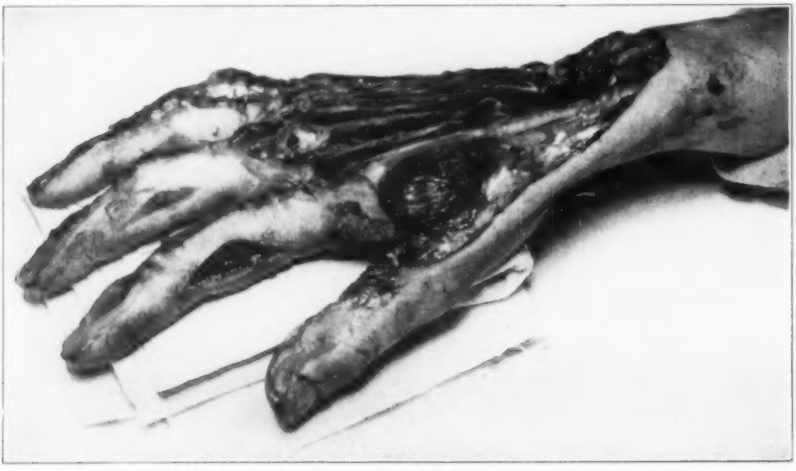

FIG. 4-B

Finger joints have been resurfaced by bipedicled flaps from the sides of the digits, and the dorsum of the hand and wrist has been prepared for the reception of a pedicle graft. The pocket in the carpal region is particularly vulnerable to postoperative hematoma.

FIG. 4-C

An abdominal pedicle flap, applied at the time of débridement, is shown, twenty-one days later, ready for detachment. The two black marks in the carpal region show the site of the insertion of a "compression suture" which transfixed the wrist, holding the flap snugly in the carpal pocket.

FIG. 4-D

Thirty-four days after injury, the integument was stable, but lymphoedema of the fingers was still severe. Indentation of the pedicle flap at the pocket in the carpus is apparent.

free grafts and recessed or pocketed beds. The method consists of the introduction of one or more transfixion mattress sutures, carried through the dressing, skin flap or free graft, and underlying base, emerging from the opposite skin surface (as, for example, in the transfixion of the hand), and being tied over buttons in order to pull the flap or graft snugly into position. The whole is then enclosed in a bulky fluffed gauze dressing encased in an elastic bandage. The regions which have proved most amenable to the use of the "compression suture" are the ear, cheek, lips, anterior axilla, scrotum, and hand. The

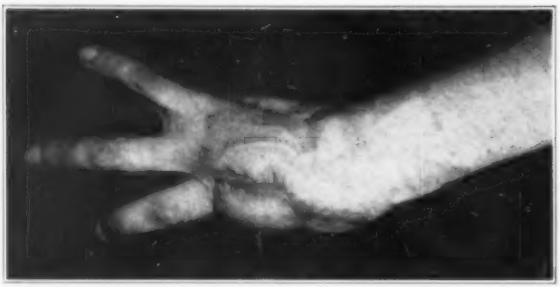

FIG. 5-A

Case 4. Hand deformity following injury from shell fragment. The site of the amputation of the first two rays has been resurfaced by a tubed pedicle flap from the abdomen. (Reproduced by permission from *Plastic and Reconstructive Surgery*, Vol. 3, p. 543, 1948.)

FIG. 5-B

The middle finger has been rotated into thumb position and the defect has been filled by a second abdominal pedicle flap. Two black dots on the surface of the flap indicate points of insertion of a "compression suture" to obliterate underlying dead space.

FIG. 5-C

Photograph of the hand following fusion of the transposed digit and tendon transfers to the opposing digits.

essential requirement is a second skin or mucous membrane surface paralleling the incised surface, on which countertraction may be obtained. The method can be most easily demonstrated by its use in surgery of the hand.

CASE 1. On the dorsum of the hand of a farmer, sixty-two years old, a nodule developed which was proved on biopsy to be squamous epithelioma. At the end of eighteen months, during which time radiation therapy had been administered for three successive periods, he was hospitalized. A persistent central ulcer was found to harbor residual disease. A period of compressing preceded an extensive resection which included the removal of the lesion together with all skin showing the effects of radiation (Fig. 2-A). The dissection hugged closely the first and second metacarpal bones and involved the removal of major portions of the first dorsal interosseous and underlying adductor muscles, which revealed marked contracture and fibrosis incidental to the radiation therapy. Frozen-section studies disclosed no tumor in the base.

The floor of the defect was too heavily scarred to make a free graft feasible, hence coverage by an abdominal pedicle flap was employed (Fig. 2-B). The conventional application of a pedicle flap on such a pyramidal type of defect fails to gain satisfactory approximation of tissues in the deepest recess of the defect and leaves the wound particularly vulnerable to the development of hematoma in the pocket. To obviate this complication a "compression suture" was used. A mattress suture of No. 0000 silk, double-armed on straight needles and incorporating a button in the loop was passed through the pedicle flap and carried directly through the underlying remainder of the adductor muscle onto the palm of the hand where it was tightened over a second button after fluffed gauze was carefully packed within and around the dorsal loop (Fig. 2-C). A bulky envelope of fluffed gauze retained by an elastic bandage completed the dressing. Satisfactory adherence ensued and the flap was detached and set in three weeks later.

CASE 2.* A case of Dupuytren's contracture was treated by radical resection of the palmar fascia,

* Case report from the Veterans Administration Hospital, White River Junction, Vermont. Published with permission of Chief Medical Director, Veterans Administration, who assumes no responsibility for the opinions expressed or the conclusions drawn by the author.

including excision of intertendinous septa and fascial extensions into the proximal phalanges, leaving a residual space, which is prone to collect blood or serum. The conventional dressing, in which an elastic bandage encircles the palm, increases palmar cupping and renders the operative site susceptible to hematoma. To obviate this a mattress suture of No. 0000 braided silk, double-armed, was passed under direct vision through the second and fourth intermetacarpal spaces, avoiding neurovascular bundles and entering distal to the volar arches and the transverse component of the ulnar nerve (Fig. 3). The closure of the wound was then completed, packing was carefully placed between and around the loops on both palmar and dorsal surfaces, and the suture was tightened over buttons, the packing being firmly pressed into the cup of the palm to obtain secure contact. The entire hand was then placed in a functional position and was carefully enclosed in a fluffed gauze dressing retained by an elastic bandage.

Of six cases treated in this manner, five healed with no bogginess or hematoma; in one, however, in which the suture was placed through the central intermetacarpal spaces, a small, localized collection of blood, which did not impair convalescence, developed at one edge of the incision.

CASE 3. A leather worker, twenty-seven years old, sustained a severe disintegration of the dorsum of the hand and wrist from contact with a heavy-duty buffing machine. Examination two hours later revealed a loss of all the soft-tissue structures of the dorsum of the hand, four fingers, base of the thumb, and wrist (Fig. 4-A). The only intact tendon was the extensor carpi radialis longus. The extensor mechanism of all four fingers was either absent or so badly fragmented that complete removal during the débridement was necessary. The dorsal third of all the phalanges and the dorsal half of the metacarpals of the fingers had been rubbed away widely exposing all finger joints; the carpal bones together with the articulating ends of the radius and ulna had been ground down through two-thirds of their substance, creating a marked indentation in the carpal region (Fig. 4-B).

Surgical repair was designed to resurface all exposed areas at the primary procedure. After a thorough débridement of all devitalized tissue, which included scraping leather dust out of the exposed bones and joints, the fingers were resurfaced by advancing bipedicled skin flaps from each side to the dorsum where the flaps were approximated and the lateral defects were covered by free grafts. Denuded bone on the dorsum of the distal phalanges was covered directly with free grafts. The residual defect on the dorsum of the hand and wrist was covered by an abdominal pedicle flap brought across the radial aspect of the hand (Fig. 4-C). The only significant problem was posed in the carpal region by the deep excavation which prevented the effective maintenance of contact between the flap and the floor of the depressed area. In order to minimize the sharpness of the wall of the pocket, the extensor carpi radialis longus tendon was detached from its insertion and the abdominal flap was pulled down into the defect by a "compression suture" in the manner previously described, the needles being run directly through the flap and then through the wrist, and the loop tied over a second padded button on the volar surface. The accumulation of fluid in this vulnerable pocket was avoided, and the flap was detached and inserted twenty-four days after its application. After three months, the extensor tendons of the wrist and thumb were reconstituted; and the patient is now, two months later, ready for reconstruction of the extensor-tendon mechanism of the fingers (Fig. 4-D).

CASE 4. * As a result of a shell-fragment injury, a soldier, twenty-three years old, sustained a loss of the first and second rays, shortening of the middle finger due to loss of the entire metacarpal, and fragmentation of the greater and lesser multangular bones of the right hand. Previous to his admission to Cushing General Hospital, an abdominal pedicle flap had been applied to the radial side (Fig. 5-A). A reconstruction of the thumb by transposition of the middle finger to the thumb position was carried out according to the method described by Tanzer and Littler. The interdigital cleft between the middle and ring fingers was deepened; and the finger was rotated into a position of opposition, carrying with it intact flexor tendons, digital artery, and nerves. This manoeuvre created between the third and fourth metacarpals a large defect which was resurfaced by a second abdominal pedicle flap (Fig. 5-B). The deeper portion of the defect resembled somewhat an inverted pyramid, making satisfactory application of a flap most difficult. To obviate the development of hematoma, a "compression suture" was carried through the center of the flap, traversing the pocket and emerging on the palm of the hand. A bolus of fluffed gauze beneath the dorsal loop of the suture was pulled down onto the flap, effectively eliminating the underlying pocket. The rotated proximal phalangeal bone was allowed to rest freely against the carpus during the transposition and ten weeks later was fused to the carpus in proper position (Fig. 5-C). Mobility of the transposed digit was restored and the ring finger was stabilized by means of tendon transfers. (Fusion and tendon transfers were done by Dr. J. W. Littler.)

DISCUSSION

The "compression-suture" technique has a definite advantage over the conventional

* Case report from the former Army Plastic Center, Cushing General Hospital, Framingham, Massachusetts.

manner of applying pressure by means of fluffed gauze and elastic bandage. The latter method, in order to maintain effectively a pedicle flap in contact with a depressed bed, not only diffuses its pressure over the entire area of saucerization, but also brings maximum pressure to bear upon the lip of the saucerized or pocketed area, thus creating a pressure distribution which makes necrosis probable. The advantage of the "compression suture" is that the pressure is brought to bear upon an area of the flap which is relatively small but which is particularly important in avoiding fluid collections. The periphery of the flap may then be dressed lightly in the conventional manner, while the maximum blood supply is preserved. We have noted no difference in healing whether the "compression suture" is placed parallel or at right angles to the longitudinal axis of the pedicle flap, although theoretically the former should interfere less with its blood supply. In using this method, there is little danger of devitalization if reasonable caution is used in tightening the suture; in fact, necrosis has not occurred in any of the cases in which we have utilized it.

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RECONSTRUCTIVE SURGERY FOR DEFECTS IN THE SHAFT OF THE ULNA IN CHILDREN *

BY CARMELO C. VITALE, M.D., BROOKLYN, NEW YORK

From The House of St. Giles the Cripple, Brooklyn

Not infrequently the orthopaedic surgeon is confronted with deformities of the forearm in growing children which present difficult problems of management. The fact that there are bones of unequal size in the forearm and that growth may affect each bone to a different degree adds to the difficulty. When congenital in origin, these deformities may be associated with partial absence of one of the bones of the forearm. Other factors causing similar problems may be benign growths (such as osteochondroma), infection, and trauma.

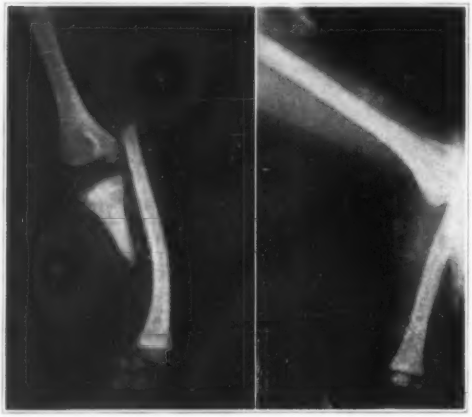

FIG. 1-A

In congenital defects of the forearm many bizarre combinations may occur. For example, there may be complete absence of either or both bones, partial absence of radius or ulna, or both. In partial absence of either bone, the proximal or distal end may be missing.

In any event, it is a rather difficult matter to decide which patient will be

* Read at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 25, 1952.

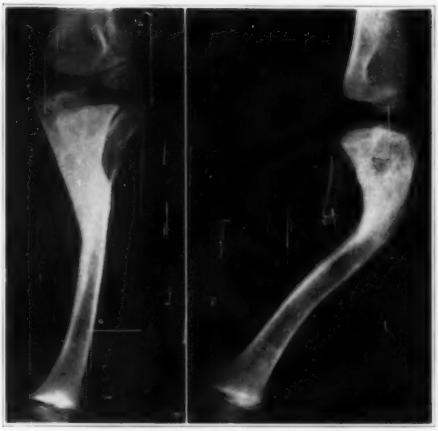

FIG. 1-B

FIG. 1-C

Fig. 1-A: L. S., a four-year-old male with deformity of the left forearm due to congenital absence of the distal end of the ulna. Films show the defect of the ulna with subluxation of the radial head. At surgery the distal end of the ulna was fixed to the radial shaft. The head of the radius was not disturbed.

Fig. 1-B: Roentgenograms made two years later revealed solid union at the radio-ulnar juncture, with angulation present.

Fig. 1-C: Nine and one-half years after surgery stability and mobility of elbow and wrist joints were good. Ulnar deviation of the hand remained, but angulation had diminished with growth. The radial head was below the level of the elbow joint. The medullary canal extended through the entire shaft. The epiphyseal plates of the olecranon process and of the lower end of the radius had not fused.

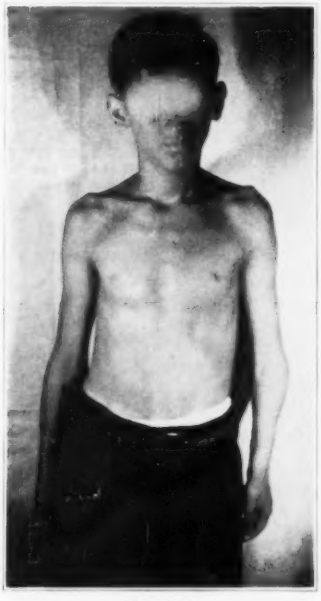

FIG. 1-D

FIG. 1-E

Fig. 1-D: Photograph made August 14, 1951, shows the atrophy and the inequality in length of the upper extremity.

Fig. 1-E: Photograph taken on the same day, showing fixed rotational position of the left forearm, as well as the ability of the thumb to approximate tips of the fingers. The wrist is stable, but it is in ulnar deviation.

benefited by surgery. Proper selection of cases is important. It is essential that there be integrity of the elbow and wrist joints. A well functioning and stable elbow joint is dependent on the articulation of the lower end of the humerus with the greater sigmoid notch of the ulna. On the other hand, the stability of the wrist is determined by the articulation of the lower end of the radius with the carpus. Expressed simply

this means that the ulna "makes" the elbow; the radius "makes" the wrist. Regardless of the defects of the radius or ulna or both, so long as the elbow and wrist-joint structures are adequate, mobile, and stable, surgery can be depended upon to join the fragments into a single satisfactory forearm bone. This will not only retain motion at both joints, but will add stability to the forearm. Furthermore, when the proximal end of the ulna is joined with the distal end of the radius into one bone, longitudinal growth is renewed, so that a better looking and longer forearm results.

Radio-ulnar fusion in the adult or the formation of a single forearm bone has been described by Hey Groves and others.

The writer is unaware of any reports of radio-ulnar fusion performed in growing children with ulnar defects.

The purpose of this paper is to report the successful application of radio-ulnar fusion to large shaft defects of the ulna in two children. In one the defect was congenital, in the other it was due to a large osteochondroma which required resection of the lower half of the ulna. In both cases radio-ulnar fusion was done, with good cosmetic and functional results. There was, of course, a loss of rotation of the forearm.

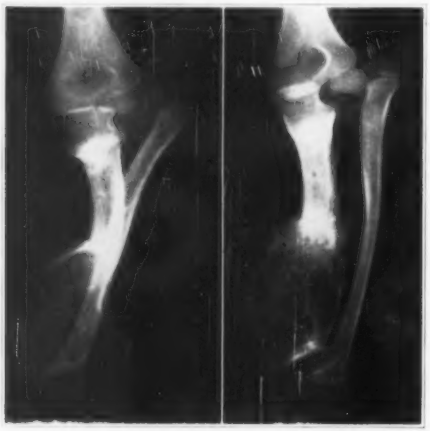

FIG. 2-A

CASE REPORTS

CASE 1. L. S., a white male, four years old, was first seen at The House of St. Giles the Cripple in May 1941, with deformity of the left forearm since birth. There was marked shortening and bowing. Mobility of all structures was free and painless except for 10 degrees' lack of complete extension of the elbow. There was extreme weakness in the grip of the hand. Roentgenograms (Fig. 1-A) revealed a congenital absence of the distal end of the ulna. Surgery was advised, but the child did not return until March 1942. A radio-ulnar fusion was done on April 22, 1942.

A lateral incision was made over the middle third of the left forearm and was carried down to the radius. Through the same incision and by blunt dissection the interosseous septum was opened. The lower end of the ulna was located, stripped of cortex, and shaped into a point. The

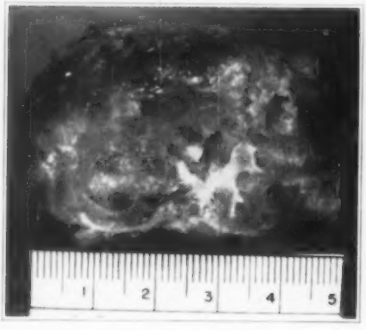

FIG. 2-B

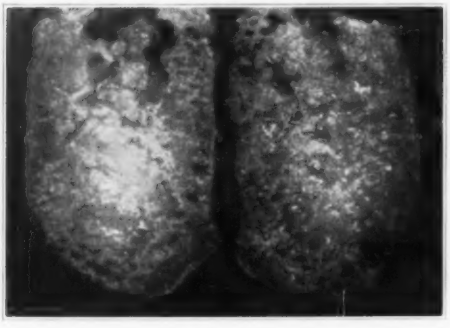

FIG. 2-C

Fig. 2-A: L. P., four-year-old female with deformity of the left forearm. Roentgenograms made April 5, 1949, revealed a large osteochondroma in the distal half of the ulna with luxation of the radial head.
Fig. 2-B: Gross appearance of the mass excised on June 1, 1949.
Fig. 2-C: Cross section of the same specimen.

FIG. 2-D

Low-power photomicrograph (× 45) of the specimen removed. (Hematoxylin and eosin stain.)

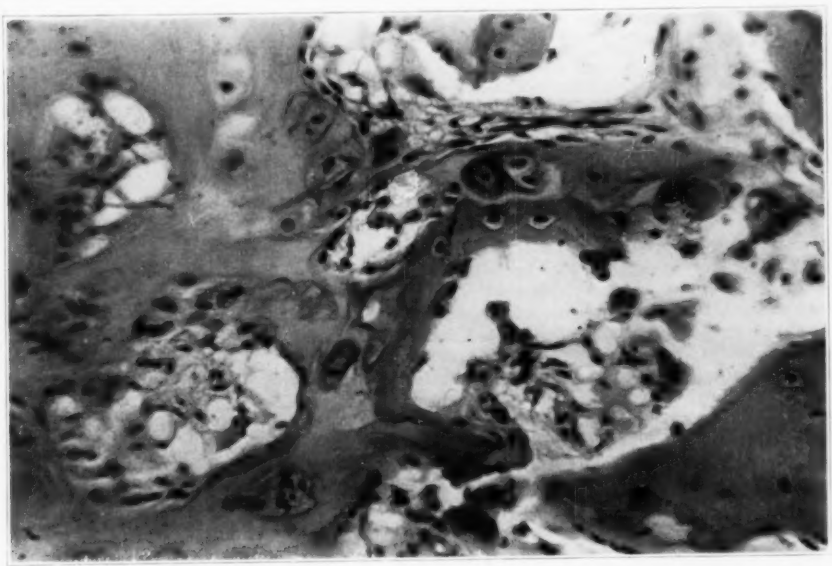

FIG. 2-E

High-power magnification (× 350) of the same specimen. (Hematoxylin and eosin stain.)

proximal end of the radius was sectioned one and one-half inches above the level of the lower end of the ulna. The lower pointed end of the ulna was next driven into the medullary cavity of the radius. Both bones were fixed with chromic catgut sutures placed through drill holes. The extremity was immobilized in a split plaster

FIG. 2-F

FIG. 2-G

FIG. 2-H

Fig. 2-F: Roentgenograms of the same child two and one-half years after surgery. The ulna and radius are fused. There is angulation at the juncture. The elbow and wrist are stable and mobile. The proximal end of the radius appears to be growing longer, but at present this does not interfere with function. Note presence of a small osteochondroma on the lower end of the radius.

Fig. 2-G: Photograph made October 31, 1951, showing the shortening and slight cubitus varus of the left upper extremity. Cosmetically and functionally the left forearm is good.

Fig. 2-H: Photograph taken on the same day, showing fixed position of the left forearm. Stability and mobility of the left wrist and elbow are good.

encasement with the elbow at 90 degrees and the forearm in neutral rotation. In this patient the head of the radius was not removed. It had been planned to remove it at a later date, but at present there is no need for such a procedure (Figs. 1-B and 1-C).

After operation a moderate reaction developed, with considerable swelling of the hand. This subsided after three days. A slight skin slough developed around the incision, but later healed. All retentive apparatus was removed on October 13, 1942, five and one-half months after operation, at which time solid union was evident both clinically and by x-ray. This child has been followed to the present. When he was last seen, at thirteen years of age, the left forearm was fixed in mid-position, with some ulnar deviation of the left hand at the wrist. Motion at the elbow and wrist is excellent. The hand is very useful, but there is some limitation of flexion in the fingers, which has probably been present since birth. The left upper extremity is two inches shorter than the right, measured from the tip of the acromion to the radial styloid.

CASE 2. L. P., a white female, four years old, was admitted to The House of St. Giles the Cripple for deformity of the left forearm, noticed soon after birth. There was a familial history of multiple osteochondroma for four generations.

Roentgenograms of the left forearm revealed a large osteochondroma involving the distal half of the ulna, with dislocation of the left radial head.

On June 1, 1949, a radio-ulnar fusion was done.

Through a longitudinal dorsal incision, the distal half of the ulna, which included the osteochondroma, was excised. A second anterolateral incision was made, beginning at the elbow crease and extending down

four inches just lateral to the biceps tendon. The brachioradialis, long and short wrist extensors, and the musculocutaneous nerve were retracted laterally. The recurrent radial artery and vein were ligated. The supinator muscle was then stripped off the radius, allowing excellent exposure of the anterior surface of the proximal end of the radius. The head and neck of the radius were excised subperiosteally for a distance of two and one-half inches. The interosseous membrane was bluntly exposed and the radius was fixed to the ulna with two Vitallium screws, after as much length as possible had been obtained. In this patient an end-to-side approximation was done so that, in the event that non-union resulted, there would be little sacrifice of forearm length if further surgery were attempted. A plaster-of-Paris cast from the palmar crease to the axilla was applied, with the elbow at 150 degrees of extension and the forearm in mid-pronation. The post-operative course was uneventful. All retentive apparatus was removed on December 14, 1949, six and one-half months postoperatively.

When the patient was last examined, on November 14, 1951, the left elbow showed a range of motion from 80 degrees in flexion to 180 degrees in extension. No pronation or supination was present. There was a slight cubitus varus. Grip in the left hand was good. The left upper extremity was one and one-half inches shorter than the right.

Roentgenograms of the skeletal system of this child, made on November 14, 1951, revealed osteochondromata involving the distal ends of both radii, the upper end of the right humerus, the anterior aspect of the left seventh rib, both femora at the distal ends, and both tibiae distally. At present these lesions do not warrant surgical intervention.

SUMMARY

Radio-ulnar fusion can be expected to improve the function, stability, and appearance of the forearm when either bone shows large defects in the shaft and when there is good stability of the elbow and wrist.

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2. Watson-Jones, Reginald: Reconstruction of the Forearm after Loss of the Radius. British J. Surg., **22**: 23-26, 1934.

DISCUSSION

Dr. Mather Cleveland, New York, N. Y.: The sole purpose of the upper extremity in man is to serve the tactile and prehensile fingers of the hand. If the hand is useless, little purpose is served in operative surgery on the upper extremity. Dr. Vitale has shown two patients with good hands, but with disability because of disturbance in growth or development of the bones of the forearm, the ulna in each instance. He has succeeded in reconstructing a forearm consisting of a single bone which is stable and able to serve quite adequately the tactile and prehensile fingers of the hand.

The need for this particular surgical procedure is fortunately rare. The prerequisites are a reasonably good proximal end of the ulna, good elbow joint, and a reasonably good distal end of the radius and radiocarpal joint.

I see no reason why this procedure should not be used in certain instances in which severe trauma, such as that due to gunshot wounds of the forearm, might result in loss of the distal end of the ulna. This has been done, I am told, in our military hospitals.

I should like to commend Dr. Vitale for the presentation and follow-up of this ingenious surgical makeshift, which may lessen the disability of some few handicapped.

Dr. Leo Mayer, New York, N. Y.: Dr. Vitale has described in his paper an ingenious method of overcoming large defects of the ulna in growing children. He has stressed as the cardinal principle of his operation the retention of the ulna at the elbow and of the radius at the wrist, in order to maintain the integrity of these two joints. In both his patients he was able to preserve almost the normal range of motion except for pronation and supination, which, of course, had to be sacrificed. The results were excellent and should encourage other surgeons to perform a similar type of reconstruction operation under similar conditions.

In my own experience I cannot recall a single case in which this type of operation was indicated. I have seen a number of large osteochondromata of the distal portion of the ulna, but simple resection sufficed to give satisfactory results. This was no doubt due to the fact that I never had to sacrifice more than a quarter of the length of the ulna. The proximal portion of the ulna, anchored to the radius by the interosseous membrane, gave good support to the elbow. Were it necessary to remove more of the ulna, I should probably, in my ignorance of Dr. Vitale's operation, have inserted a fibular graft. Whether the result would have been as good as Dr. Vitale's I doubt.

In another group of cases there has been a defect of the ulna due to sequestration resulting from osteomyelitis. In these, after a suitable lapse of time, I have inserted autogenous bone grafts.

There is an important congenital deformity which has unquestionably presented itself to Dr. Vitale: club-hand due to absence or underdevelopment of the radius. These cases point up the importance of Dr. Vitale's statement with regard to the essential support given the wrist by the radius. Without the radius, the function of the hand suffers greatly. I wonder whether Dr. Vitale has been able to solve this problem.

Historically it is of interest to note that almost fifty years ago Dr. Reginald Sayre [c] reported an excellent result in such a case by a radial shift of the ulna, so that it articulated with the lunate bone. Albee [a] employed a tibial graft, running from the mid-shaft of the ulna to the radial side of the wrist. George Bennett [b] splits the ulna into an anterior and a posterior half and shifts one of these to the radial side of the wrist. I should be interested to know Dr. Vitale's answer to this problem.

a. Albee, F. H.: Bone Graft Surgery in Disease, Injury and Deformity, pp. 258–260. New York, D. Appleton-Century, 1940.

b. Bennett, George: Personal communication.

c. Sayre, R. H.: A Contribution to the Study of Club-Hand. Trans. Am. Orthop. Assn., **6**: 208–216, 1893.

Dr. Vitale (closing): I want to thank both discussors for their kind remarks.

As regards the congenital absence of the radius, I have not yet been confronted with that problem. I would probably shift the ulna into the carpus.

DISCUSSION

The Treatment of Bone and Joint Tuberculosis: Effect of 1-Isonicotinyl-2-Isopropylhydrazine

(*Continued from page 771*)

This must, of course, be considered as a preliminary report, since the cases are relatively few and the period during which they have been observed is short. In view of the desperate nature of the cases, however, the results thus far must be regarded as quite remarkable. We must not lose sight of one point, which is that there is no proof that iproniazid can supplant surgery in the treatment of bone and joint tuberculosis. Dr. Bosworth does not believe this and makes no such claim.

Several questions naturally occur in attempting to explain the effects of the drug. Is the generally marked improvement in the condition of the patients due alone to the suppression of the tubercle bacilli, or is it due to a general effect on bettering nutrition and lifting the patient's morale by a stimulating action in the central nervous system? This cannot be definitely answered, but it seems certain that the growth and activity of the tubercle bacilli have been checked, as demonstrated by the nature of the exudate from the wounds and sinuses and by the number of negative cultures obtained. The same question is posed in regard to the reasons for the stimulation of wound healing. Is it due to improved nutrition and a higher serum protein, or is it due to the elimination of tubercle bacilli? It is possible that both of these factors play a part.

Although iproniazid does have a toxic action when given in too large doses, it would seem that the symptoms and signs of this are quite easily recognized and that they afford ample warning, if heeded, to prevent dangerous effects.

Several laboratory investigations have reported evidence that tubercle bacilli become resistant to the drug rather quickly. There has been no clinical evidence in these cases that this has happened.

Dr. Bosworth has performed a valuable service in demonstrating the very beneficial effects of iproniazid combined with surgery in the treatment of a relatively small series of patients desperately sick with tuberculous joint lesions. It is to be hoped that further experience will confirm the promise that these early results have given.

AN EVALUATION OF SKIN GRAFTS FOR HAND COVERAGE*

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A surprising amount of disability may follow the healing of a burn, avulsion, or even laceration of the hand. Surface defects without the benefit of skin grafts heal in the quickest and most economical manner possible, for granulation tissue by contracture reduces the area to be covered by the ingrowing epithelium. In many regions a contracted surface scar causes little or no disability, but in the hand even small scars may markedly limit the mobility of function. The fact that immediate or early skin-grafting can prevent, and the proper graft to replace a contracted scar can correct, most of the disability deserves reemphasis. It is the purpose of this paper to present certain observations concerning skin grafts employed frequently in general plastic surgery, and to evaluate their application in reconstructive surgery of the hand.

A healed scar represents nature's achievement in closing any surface defect. In microscopic cross section a scar consists of a mass of fibrous tissue covered by the thin epithelial layer of the skin. The fibrous tissue may originate from the adjacent dermal layer of the skin and from the granulation tissue which develops from the deeper tissues. A

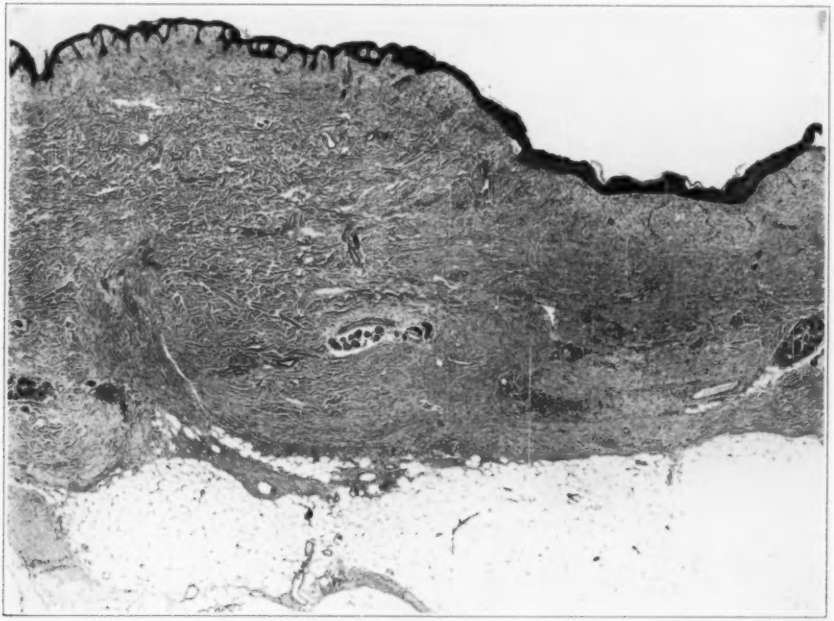

FIG. 1

Photomicrograph (× 150) showing cross section of juncture of scar tissue (right) with normal skin. Epithelial layer thickened with loss of normal papillae; normal elastic dermal layer shows no regeneration, and is replaced by dense fibrous tissue.

* Presented at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 25, 1952.

FIG. 2-A

FIG. 2-B

Fig. 2-A: Linear burn-scar contractures of index and third fingers.

Fig. 2-B: Complete correction in one operation by series of Z-plastic flaps utilizing adjacent skin of the finger.

microscopic study of the juncture of a scar with normal skin indicates that there is no true regeneration of the full elastic dermal layer over the defect. While there may be some dermal elements in the fibrous mass, we observe an absence of orderly arrangement and a great reduction in the elastic fibers found normally in the dermal layer of the skin. Thus, dense fibrous tissue replaces the dermal layer through a scar and the normal elasticity of skin is absent. Furthermore, the fibrous mass contracts, with resultant great loss of function in the hand.

FIG. 3-A

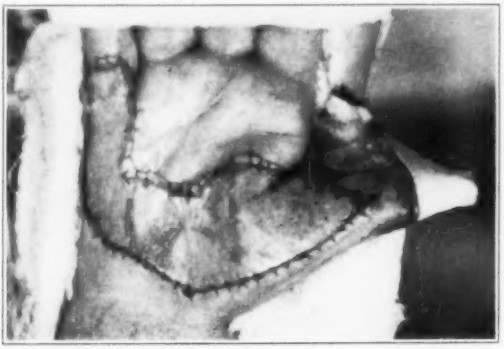

FIG. 3-B

Fig. 3-A: Contracture of proximal palmar region following laceration and a severe iodine burn.

Fig. 3-B: Appearance of free full-thickness skin graft at first dressing on the ninth day after operation, showing complete take and release of contracture.

FIG. 4-A

FIG. 4-B

Fig. 4-A: Acute x-ray burn on dorsum of hand seven days after the administration of 1,400 r for treatment of warts.

Fig. 4-B: Appearance of the hand after healing, four months later. The tight contracted scar on the dorsum was later replaced by a graft.

FIG. 4-C

FIG. 4-D

Fig. 4-C: Split-skin graft nine years after application, showing that excellent function had been retained.

Fig. 4-D: Pliability of split-skin graft is demonstrated. Progression of x-ray dermatitis on the fingers is visible; resurfacing of the fingers may be required later.

General Principles Applying to Free Grafts and Pedicle Flaps

In any reconstructive work upon the hand, a constant recognition of the importance of the deeper intrinsic structures and their relation to the scar deformity must be stressed. The removal of a contracted scar should be done in an avascular field with a pressure-cuff tourniquet, with particular attention to the careful dissection of deeper extensions of the scar. For larger surface defects, grafts of skin must be secured from other areas of the body. These provide the best substitute available, but are never as good as the tissue

Fig. 5-A

Fig. 5-B

Fig. 5-C

Fig. 5-A: Six months after healing of a mangle burn of the left hand and arm, showing extreme contracture of the hand and fingers.

Fig. 5-B: Four months after replacement with thick dermatome skin graft eight inches in length.

Fig. 5-C: Appearance ten years after grafting, showing that excellent function has been maintained. The graft now measures eleven inches in length, indicating actual growth.

which normally covers the hand, particularly the palmar surface. In planning the graft, the borders should be zig-zagged or interdigitated so that no straight edge lies across a normal wrinkle line to produce contracture. For the successful "take" of a free graft immobilization is mandatory, but pressure is not necessary. Pressure dressings for grafts are preferred, however, and are employed routinely, because they aid in healing and assist in the immobilization of the graft. For replacements of palmar skin, immobilization in extension is indicated; but for all other grafts, as well as for other types of hand surgery, the position of function should be maintained on a splint, preferably the very useful metal splint described by Allen and Mason. Since the aim of replacing the contracted scar by a skin graft is to eliminate or minimize the contracture, the additional operating time required to secure an accurate approximation of the edges is well justified, for there will be a finer linear scar about the graft and hence a quicker return of function.

Excision of Scars and Z-Plastic Closure

The use of adjacent tissues to close a defect is a fundamental principle of reconstructive surgery; on many occasions this can be applied to the hand for improved functional results. In a broader sense, z-plasty and even excisions are variations of flap grafts, since tissue is undermined and shifted. In a z-plasty or a zig-zagged closure of a contracted linear scar, the undermining should include some subcutaneous fat, when available, to nourish the small flaps. The manipulation of these scar flaps with small skin hooks and fine forceps may prevent the necrosis of a portion of the closure. Z-plastic correction of linear contracted scars on the hand can give excellent functional results but, because of the

restricted surface area, this method has definite limitations when applied to the fingers. However, a properly performed z-plasty which provides full correction is better than a graft.

Other Types of Adjacent Pedicle Grafts: Finger and Hand Flaps for Small Defects

The V-Y procedure for lengthening a longitudinal contracture of the finger is of limited value, since a straight longitudinal portion of the scar remains, so that contracture may recur. An adjacent pedicle from the side of a finger to cover a flexor defect provides coverage with better sensation and protective thickness on the working surface than does a free graft. If a tendon, joint, or bone is exposed, some type of pedicle is required, and the donor site on the side of the finger may be covered immediately with a free skin graft. Bipedicled flaps to replace scar at the end of an

FIG. 5-D

Appearance of both hands showing familial abnormality; stretching and wrinkle configuration nearly normal over grafted metacarpophalangeal joints, and the graft shows moderate pigmentation on the left hand.

FIG. 6-A

FIG. 6-B

Fig. 6-A: Five months after a severe burn on the dorsum of the right hand, there was dorsal contracture of the thumb and flexion of the fingers was practically absent.

Fig. 6-B: Appearance one year after complete resurfacing with free split-skin grafts. Restoration of normal thumb position and 50 per cent. flexion of the fingers was achieved solely by skin-grafting.

FIG. 7-A

FIG. 7-C

FIG. 7-B

FIG. 7-E

FIG. 7-D

Fig. 7-A: Ulcerated x-ray burn on the dorsum of the right hand of ten years' duration, and thirty-seven years after original x-ray therapy.

Fig. 7-B: An abdominal pedicle graft was applied in a one-stage procedure. The pedicle should have been thinned to remove excess fat.

Fig. 7-C: Because of the bulky appearance of the pedicle, this was considered an unfinished result.

Fig. 7-D: Improved appearance of the pedicle after excess fat had been removed in two stages. Thinning the pedicle at the time of application is the preferred method.

Fig. 7-E: Appearance of the hand eleven years later, showing satisfactory pedicle coverage. Some increase in the x-ray dermatitis of the fingers was noted, but there was no ulceration.

amputation stump are excellent and provide a single-stage reconstruction. Flaps taken from adjacent normal fingers or from the palm to replace a contracted scar on the finger may be satisfactory, but occasionally the scar of closure or the graft covering the donor site may produce considerable disability. Thus these procedures must be planned and executed with precision and skill to avoid new scar disability of the donor area. When a useless finger is present and amputation is considered, the removal of the bones and tendons—"filleting" the finger as described by Bunnell—provides an excellent flap of adjacent tissue for replacement of a scar defect.

Free Full-Thickness Skin Grafts

By definition this is a graft of the full thickness of the skin with no fat or areolar tissue adherent to the under surface. Such grafts are entirely separated from their blood supply and are not to be confused with pedicles or flaps. Full-thickness skin grafts from the back, chest, and upper abdominal regions in the adult usually do not "take" well, because they are too thick. Theoretically and practically, of all free skin grafts a full-thickness graft supplies the best coverage. Experience has demonstrated that a full-thickness graft from the lower part of the abdomen, groin, or other comparably thin areas provides a better graft than the same thickness taken as a split graft from the thicker skin on the back. The disadvantages of full-thickness skin grafts are limitation in size when covering larger areas on the wrist and arm, a considerable increase in operating time, and occasionally the rather marked deformity of the donor site of closure. When large grafts are required, the abdominal donor site may be covered by a thinner split graft, so that less scar and disability will result. The best application for full-thickness skin grafts on the hand is to cover smaller areas and particularly to replace superficial contracted scars of the palmar surface. Even though a full-thickness graft on the palm is applied and heals with the fingers immobilized in extension, some wrinkling and contracture may occur during the next two to three months. Any split-skin graft applied to the palm, however, shows even greater contracture.

Split-Thickness Skin Grafts

In general, the thinner the split graft secured with the grafting knife or some type of dermatome, the more certain is the take; thus thin-split grafts should be applied to granulation areas and to avulsed or otherwise injured surfaces. The thinner split grafts, however, will contract more and thus provide less satisfactory surface coverage and poorer functional results. The thin-split or Ollier-Thiersch graft is eight to ten thousandths of an inch in thickness and is usually applied as a temporary coverage to secure early healing. An intermediate or thick-split graft measures twelve to twenty-five thousandths of an inch; these grafts show very little contracture when applied to the dorsum of the hand. Usually there is an abundant supply of split graft available, but on occasions thicker split grafts may be re-split upon the dermatome drum, in order to double the coverage in cases of extensive burns, as reported by White and Dupertuis and others. The split graft is secured more quickly than a full-thickness graft and the donor site usually heals promptly and well; there is minimal contracture of split grafts applied to the dorsum of the hand, but shrinkage on the palm of the hand may be considerable.

After study and consideration of a series of split-skin grafts applied to the hand, the following observations may be made. Split-skin grafts applied to the dorsum of the hand or arm in children will grow and increase in size. These grafts become almost as pliable as the normal skin on the dorsum of the hand. In two patients reviewed ten years after application of the graft, the stretching and wrinkling over the knuckles have assumed nearly a normal configuration and appearance. Most free grafts are not a perfect match in color or texture, and usually show some degree of pigmentation. Despite this disadvantage, a successful skin graft presents a better appearance than the irregular surface of a scar. At operation the normal venous network on the dorsum of the hand should be preserved, so that later it will present a natural appearance beneath the healed split graft. In patients showing evidence of early x-ray dermatitis, in which grafting is necessary, the split grafts should be larger than appears indicated, since x-ray dermatitis is a progressive, degenerative lesion and the extension about the periphery will not become evident until many years later. In several cases of extensive third-degree burns of the hand, most of the functional disability was eliminated by replacement of the contracted scar by split grafts, which have provided excellent functional coverage through a period of over ten years.

Pinch Grafts or Small Deep Grafts

There should never be an indication to employ small deep grafts upon the hand. They are unsightly; take much longer to secure and apply; and, after healing, there is too much surrounding scar in relation to the dermal element of the skin introduced to supply good functional coverage.

Pedicle Flaps and Tubed Pedicles

Whenever deeper reconstructive work involving bone, tendons, or nerves is required, a pedicle flap of skin and subcutaneous fat carrying its own blood supply is necessary. When dense masses of surface and deep scar must be dissected away, the application of a pedicle flap brings new nourishment and supplies the best pliable coverage available. For hands the closed pedicle is preferred. This is provided by the tubed pedicle or the open flap with split-skin graft applied to all raw surfaces to secure healing, as described by Macomber and Rubin. If the donor site of any pedicle is not closed, a graft should be applied immediately to prevent absorption through the pedicle from an adjacent open granulation area. The one-stage tubed pedicle procedure as described by Shaw is very desirable and has many applications. Likewise the partial-flap method as outlined by Blocker provides a simple closed method for transferring tissue, but the hand must be immobilized securely. These and most abdominal flaps do not require a preliminary delaying procedure.

All grafts should be thinned before application to the hand; excess fat can be removed safely from abdominal pedicle flaps. When the definitive deeper reconstruction is planned, it is unthinkable that another scar should be added by incision through the pedicle, since elevation of one-half of the flap provides better exposure. The pocket flap in which the hand is buried beneath the abdominal skin should be condemned as a procedure of choice, because of the foul discharge and the danger of contamination which accompanies this procedure.

Grafting in Traumatic Avulsions

After a contaminated wound has been thoroughly cleansed and irrigated with a large quantity of saline solution to provide a clean field, a split-skin graft should be applied immediately to secure healing. When the occasion demands, an immediate abdominal pedicle flap may be applied to the defect; but *no open wound should ever be left to heal with scar.* Later definitive reconstructive work may require the replacement of the original thin graft by a thicker free graft to supply a more serviceable coverage. Since free skin grafts tolerate but minimal undermining, replacement of this original graft by the proper pedicle graft is necessary when deeper reconstructive surgery is required.

Grafting in Acute Burns

In the third-degree burn, our object is to replace full-thickness skin loss with split-skin graft at the earliest possible moment. Particularly on the dorsum of the hand, where the intricate mechanism of extension may be damaged severely by prolonged absorption from granulation surfaces, a surgical excision of the slough with the application of a split graft in ten to fourteen days is desirable. Relaxation of the hand in the position of function is of great importance, and the pressure-dressing method of immobilization remains the treatment of choice.

In most instances, a split graft of intermediate thickness will provide good functional coverage, and any healing scar surrounding a granulation area should be removed to normal skin, in order to minimize scar contracture on the borders of the graft. In certain deep burns and particularly in electrical burns, an early pedicle flap may be indicated to secure healing.

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DISCUSSION

Dr. W. Brandon Macomber, Albany, New York: The material presented by Dr. Dupertuis surely leaves little to be desired as far as resurfacing of the hand is concerned. There are a few points, however, that I would like to bring out. Wrinkling of calibrated grafts in my experience has been minimal. I prefer split grafts to full-thickness grafts for resurfacing of the palm; the mortality of the full-thickness graft is greater than that of the split graft. There are certain factors which may cause wrinkling of a split graft: (1) the graft may be too thin, as was mentioned by Dr. Dupertuis; (2) since scar breeds scar, failure to remove all of the deep scar tissue will definitely cause wrinkling of the graft, whether it be a split graft or a full-thickness graft; (3) failure to put the graft on without normal skin tension will also cause wrinkling; (4) if pressure is inadequate, this will prevent the graft from conforming to all the depressions; (5) the pressure dressing itself will cause the graft to wrinkle, and this will be permanent. The splint advocated by Mason and Allen will help to keep the pressure dressing from wrinkling the graft.

In acute burns, wrinkling of split grafts often occurs after healing has taken place. Complete avulsion of the scar-forming granulations and even pressure on the split graft will prevent future wrinkling and result in a more pliable graft.

Again, the importance of a good skin covering in acute wounds cannot be overemphasized.

Dr. Harvey S. Allen, Chicago, Illinois: So often it is forgotten that a split graft can be successfully applied in a primary wound, even if the wound is contaminated, to close the gap and to convert an open contaminated wound into a closed wound. We use split grafts in amputation of the finger tip and in avulsion of the hand from roller injury, and we have found they serve very satisfactorily for complete function.

The full-thickness graft is a most exacting one, but gives the most satisfactory results. It is not, however, always necessary to go through the difficult procedure which has become standard in applying a full-thickness graft. The mortality of full-thickness grafts is rather high. However, it is believed that, if a case is properly selected and the wound is clean before the scar tissue is removed, the choice of a full-thickness graft is acceptable.

The results in split-skin grafting in the cases of burn which Dr. Dupertuis and Dr. Macomber have shown are excellent; however, in many instances I believe we must judge by the depth of the burn, for we cannot say that a split-skin graft will suffice for a burn on the dorsum of the hand. There are many cases in which the entire thickness of the skin of the hand is burned away and in which it would be useless to attempt a split graft, except to obtain closure of the wound immediately. In these cases we should use a full-thickness graft later.

MYXOMA AND MYXOSARCOMA OF THE SOFT TISSUES OF THE EXTREMITIES

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This study was an outgrowth of a discussion on the prognosis of myxomata. Opinions expressed in the course of the discussion had been based on cumulative clinical experience without critical evaluation of a series of patients. We hoped to clarify the histological classification and the prognosis.

The first step was a review of the literature. With few exceptions, it consisted of reports of individual cases. Textbooks of pathology contained various criteria for identification, and usually the authors recognized benign and sarcomatous types. We found only one report of material comparable to ours in quantity. This was the report of Stout[1], who reviewed thirteen tumors of the subcutaneous and aponeurotic tissues of the extremities, which he designated as myxomata. He found these thirteen tumors in a study of forty-nine of his cases in which the tumors were distributed throughout the body.

Direct quotations from Stout's article are submitted because our study was initiated by our reading of his work:

"Yet the literature contains very little accurate information about them [myxomata] as an entire group. . . . In the first place, there are a number of tumor forms which sometimes are composed in part of myxoid tissue such as liposarcoma, fibrosarcoma, chondrosarcoma, and mesenchymoma. Such tumors sometimes have 'myxo-' included as part of the name and there has been a tendency to consider them as variants of the myxoma. This is certainly an error, for clinically they behave like tumors composed of the dominant tissue and should be designated by that name. Further, there has been a tendency on the part of some to use both the terms myxosarcoma and myxoma. This also is probably unwise, for *myxomas do not metastasize and there is no way to anticipate differences in their growth energy from their histopathology.* Still another difficulty arises because of the resemblance of ganglions of the tendon-sheaths and skin to myxomas. . . . For these reasons it is quite difficult to learn accurately from the literature the exact distribution and biological course of this group of tumors." *

Stout's opinions impelled us to review our own regarding the ability of the so-called myxomata to metastasize and regarding the ability of the pathologist to anticipate, by histopathological study, what the growth potentialities of these tumors are. We attempted to fulfill Stout's criteria for "myxoma" when selecting cases for study.

DEFINITIONS

Stout's definition is quoted:

". . . it is a true neoplasm composed of stellate cells set in a loose, mucoid stroma through which course very delicate reticulin fibers in various directions. In other words, it closely resembles primitive mesenchyme. . . . The only variation from this is the occasional formation of denser areas due to a thickening of the delicate connective tissue fibers and a lessening of the mucoid material. In such areas, because of this increase in density, some of the cells may become spindle-shaped, probably as a result of pressure molding, but these areas should not be extensive. One must allow this much variation, since any tumor may undergo some degree of fibrosis. There must be no chondroblasts, lipoblasts, rhabdomyoblasts or any other recognizable differentiated elements. . . . Perhaps most important of all, the myxoma does not metastasize and, if it kills, it is because of damage to vital structures produced by infiltrative or expansile growth causing pressure or erosion."

* The word in brackets and the italics have been supplied by the authors of this article.

We shall show why we believe that, contrary to Stout's opinion, both terms, "myxoma" and "myxosarcoma," should be retained. In fact, we believe that neoplasms which in all respects correspond to Stout's description of myxoma are susceptible of being divided into myxomata, which are benign, and myxosarcomata, which are malignant. As will be seen, we also found one tumor which fell into an intermediate group.

MATERIAL AND METHODS

We reviewed tumors of the extremities which had been placed in the pathology museum at the Mayo Clinic between 1910 and 1945 and which were myxomatous in nature. The card references were studied. All tumors classified as myxomata, myxosarcomata, fibromyxomata, fibromyxosarcomata, myxolipomata, myxoliposarcomata, myxochondromata, and other tumors classified under diagnoses suggesting myxomatous tumors were listed. Cross verification was obtained by reference to the file on tumors of the extremities based on diagnoses at the time of dismissal of patients. Available sections, or new sections of blocks cut from gross specimens, were reviewed microscopically. Several hundred slides were reviewed.

FIG. 1
Case 12. Table II. Myxosarcoma.

From this selected group, approximately fifty possible myxomata were identified. The gross specimens of the majority of the fifty tumors were examined. Multiple sections were taken from each tumor. Hematoxylin and eosin and van Gieson stains were used, as well as Gömöri's silver-impregnation method of staining. Many tumors were rejected for further study because myxoid tissue was not the only tissue present. If there was doubt concerning the diagnosis of a tumor, it was not included. A myxoma of bone was not encountered, but exhaustive search for such a neoplasm was not made. In all, sixteen tumors were found which we thought fulfilled Stout's criteria for myxoma (Figs. 1 to 8-B).

SEPARATION OF THE SUPPOSED MYXOMATA INTO BENIGN (MYXOMA) AND MALIGNANT (MYXOSARCOMA) TYPES ON THE BASIS OF MICROSCOPIC STUDY

Upon the review of the sixteen tumors selected, it became apparent that two distinct types were present. The differential features were found mainly in the vascular patterns and in the types of silver-staining fibrils. The characteristics of each group are presented below. For clarity, the gross descriptions are presented first.

Myxomata

Gross Appearance: These tumors were watery and gelatinous, and occasionally there were cystic inclusions. They were poorly encapsulated but did not appear to be infiltrating. Rather fine septa divided them into lobules. Each tumor was fairly uniform in color, but one might be white and another gray. Necrosis was not obvious. The tumors were of irregular shape. Some of those which were roughly spherical were slightly less than one centimeter in diameter. Others measured, in the various diameters, seven by 4.5 by 4.5 centimeters.

Microscopic Appearance: The tumors were composed predominantly of stellate cells sparsely distributed in a mucoid matrix. In some portions the cells were spindle-shaped

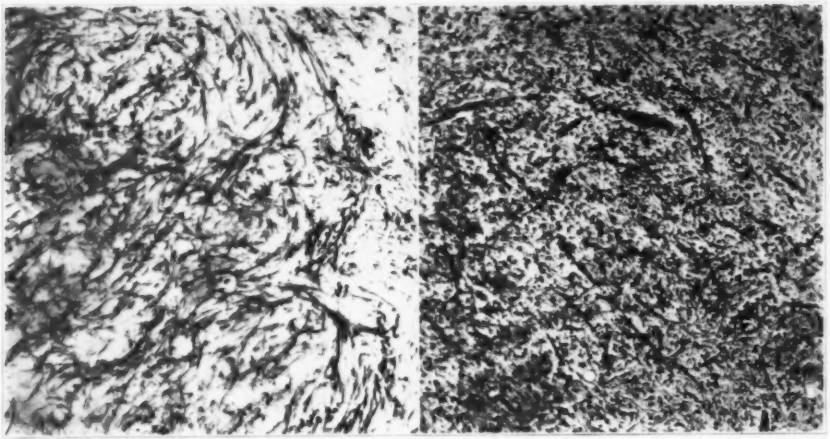

FIG. 2 FIG. 3

Showing absence of vascular pattern in myxoma and its presence in myxosarcoma (hematoxylin and eosin stain, × 65).

Fig. 2: Case 2, Table I. Myxoma. No vascular pattern is evident. Light has been reduced to show fine non-collagenous fibrils of reticulin.

Fig. 3: Case 9, Table II. Myxosarcoma. Definite vascular pattern is seen; the fibrillar pattern is indiscernible with routine stain.

or oval. Septa were composed of mature fibrous-tissue elements. There was no evidence of active fibroplasia. The nuclear pattern varied, but in general the nucleus was centrally located and filled most of the cell. The stellate appearance of the cells was derived from their membrane and cytoplasm. The capillaries were very sparse and without relationship to the cells.

In sections stained in the routine manner with hematoxylin and eosin, the presence of fine, long, flowing and intertwining fibrils of uniform appearance was suggested. In

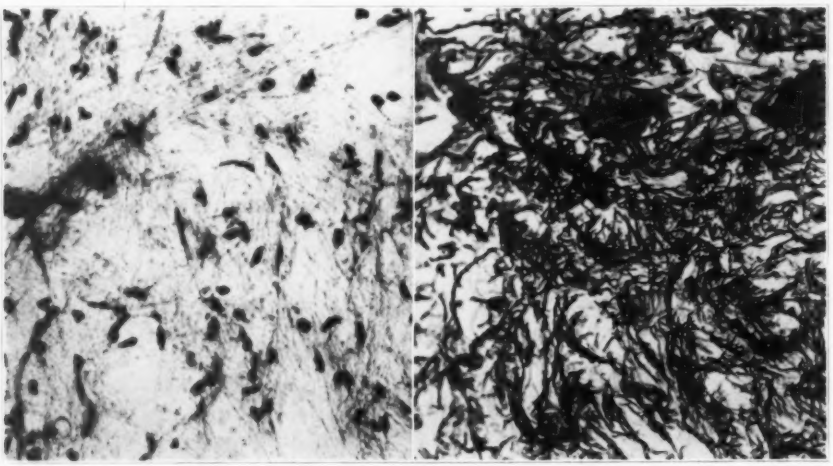

FIG. 4 FIG. 5

Fig. 4: Case 5, Table I. Myxoma. Light has been reduced to show fine, non-collagenous fibrils (hematoxylin and eosin stain, × 235).

Fig. 5: Case 6, Table I. Myxoma. Longer and non-anastomosing reticulin fibrils (silver stain, × 235).

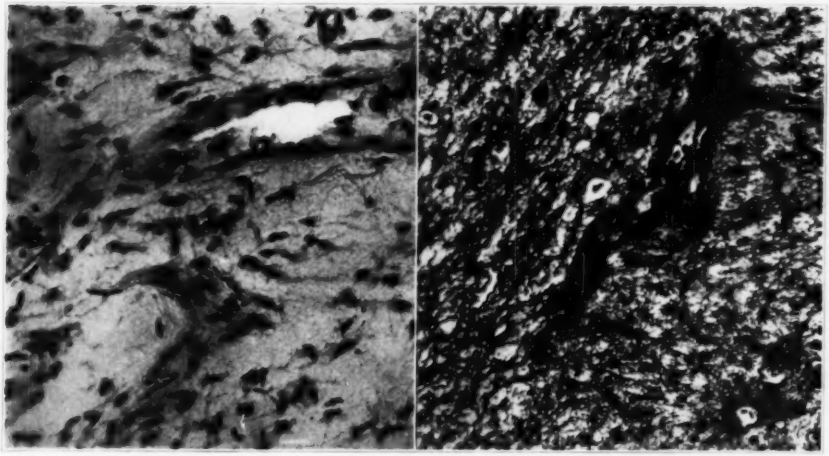

FIG. 6-A FIG. 6-B

Myxosarcoma: Case 12, Table II. Sections from primary tumor.

Fig. 6-A: Vascularity, with perivascular cellular concentrations, is evident; reticulin is very poorly stained (hematoxylin and eosin stain, × 235).

Fig. 6-B: Section from the same specimen, showing reticulin and short, tortuous, and anastomosing fibrils (silver stain, × 235).

sections stained with the silver impregnation technique, it was demonstrated that these fibrils had a strong affinity for the silver stain. We shall refer to these elements as "silver-staining fibrils" because we have not wished to enter the discussion whether they are composed of reticulin or whether they are precollagenous fibers.

Study of the sections stained with van Gieson stain did not contribute to the separation into two groups. These sections did demonstrate that condensations of the silver-

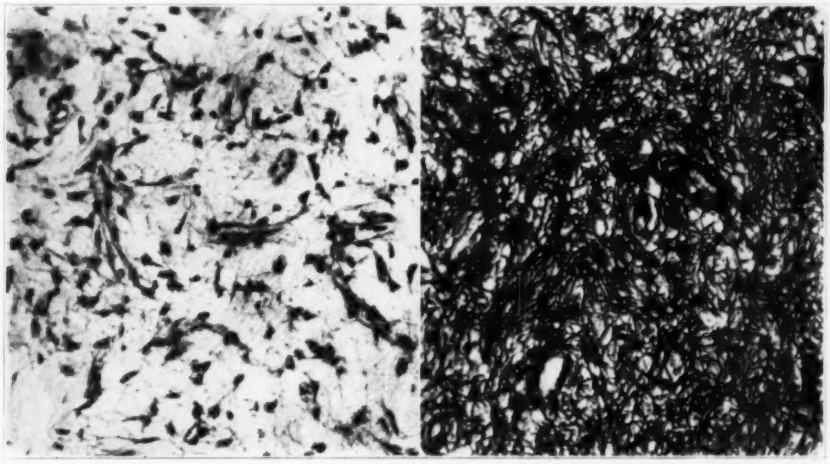

FIG. 7-A FIG. 7-B

Myxosarcoma: Case 16, Table II. Sections from a recurrent tumor.

Fig. 7-A: Vascularity with some perivascular cellular concentrations is shown; reticulin is very poorly stained (hematoxylin and eosin stain, × 235).

Fig. 7-B: Section from same specimen, showing reticulin and short, angulated, and anastomosing fibrils (silver stain, × 235).

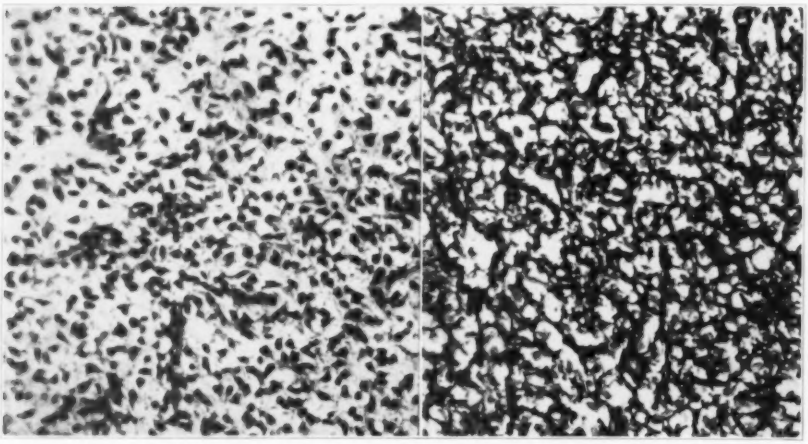

FIG. 8-A FIG. 8-B

Myxosarcoma: Case 15, Table II. Sections from one of multiple subcutaneous metastatic tumors of the trunk.

Fig. 8-A: Vascularity, with perivascular cellular concentrations, is evident; tissue is more cellular than in the other cases (hematoxylin and eosin stain, × 235).

Fig. 8-B: Section from the same specimen, showing reticulin: the fibrils are irregular in caliber, angulated, and anastomosing (silver stain, × 235).

staining fibrils caused the development of septal and capsular elements which were indistinguishable from mature fibrous tissue. We have noted such a transition from fine fibrils to red-staining condensations in the human umbilical cord (Wharton's jelly), which is considered to be the only truly myxomatous tissue normally occurring in the human body. Fibrous tissue also was seen along blood vessels. Fibroplasia with production of new collagen was not noted.

Myxosarcomata

Gross Appearance: These tumors were falsely encapsulated or infiltrating. The false capsules were formed by compression of normal connective tissue, especially fibrous and fatty tissue. Recurrent tumors were more likely to be infiltrating than primary tumors. Metastatic growths were not available for gross study. In general, the mass of the tumors was gelatinous. Lobulation was formed by fine or coarse septa. Evidence of necrosis was observed in some large tumors. Some tumors were homogeneous; others varied in color and consistency. Colors varied from grayish white to yellowish white and pink. One tumor was slightly more than one centimeter in all diameters, whereas another measured thirty-four by twenty-nine by eighteen centimeters in various diameters.

Microscopic Appearance: The tumors were composed, predominantly, of stellate cells in a mucoid matrix. The shape of the cells varied more than did that of the cells of myxomata. In some portions were concentrations of cells, the nuclei of which tended to stain more deeply than did the nuclei of other cells. In some of the tumors mitotic figures were found occasionally.

These tumors were more vascular than were the myxomata. The numerous capillaries appeared to form a geometric alveolar arrangement. There were cellular concentrations about the capillaries.

The silver-staining fibrils were characteristically more variable in thickness than they were in the myxomata. The fibrils of the myxosarcomata were short, kinky, and anastomosing. Individual fibrils varied in diameter and seemed to form a meshwork

TABLE I

MYXOMA

Case	Age at Onset (*Years*)	Site	Treatment	Recurrence
1	65	Finger	Excision	None in 4 years
2	62	Finger	Excision	Only 6 months' follow-up
3	64	Finger	Excision	None in 10 years
4	45	Foot	Excision	None in 7 years
5	50	Arm	Excision	None in 21 years
6	55	Under deltoid	Excision	Unknown
		INTERMEDIATE TYPE		
7	53	Forearm	Excision 6 times in 6 years; then wide excision and skin graft	None until 23 years after excision and skin graft. Late recurrent tumor was excised and patient was known to be well for 8 years.

about individual cells. Study of the sections stained by the van Gieson method did not contribute to the differentiation between the two groups.

COMPARISON WITH OTHER CONNECTIVE-TISSUE ABNORMALITIES

The possibility that myxomata might actually be adventitial bursae was suggested by their occurrence in the finger tips and feet and in subcutaneous tissues. For comparison, microscopic sections forming the bases of theses on bursae and ganglia were studied. As a result, we are convinced that myxomata are not variants of adventitial bursae or ganglia.

CLINICAL CORRELATION OF THE TWO GROUPS WHICH WERE DISTINGUISHED HISTOPATHOLOGICALLY

Examination of the clinical records was made after the sixteen tumors had been divided into myxoma, myxosarcoma, and one intermediate type. No changes from one group to another were made as a result of study of the clinical course. We believe it to be significant that in all cases in which the histopathological diagnosis was myxoma, the clinical course had been benign. In those cases in which the histopathological diagnosis was myxosarcoma, the clinical course had been protracted; three of the nine patients succumbed to metastatic spread of the original tumors.

Myxomata

In six of the sixteen cases the tumors were diagnosed as myxomata. Table I illustrates the significant clinical information. No recurrence is known to have taken place. No patient is known to have died from the tumor. Five of the six tumors appeared in an upper extremity and the other in a foot. Generally the tumors were superficial. They appeared later in the lives of the patients than did their malignant counterparts. Local excision appeared to be adequate treatment.

Myxosarcomata

Significant clinical differences were noted in the cases of myxosarcoma when compared with the cases of myxoma (Table II). As has been said, three of the nine patients succumbed to metastasis. The recurrence rate was very high; seven of the nine patients

TABLE II

MYXOSARCOMA

Case	Age at Onset (*Years*)	Site	Treatment	Recurrence after Last Operation
8	43	Thigh	Primary amputation	None in 21 years
9	49	Thigh	Excision 5 times in 3 years	Unknown
10	34	Thigh	Excision 3 times in 15 years	None in 14 years after last excision
11	39	Perineum	Excision, once	Recurred at unknown date. Patient lived for 30 more years
12	51	Thigh	Excision, once	None in 4½ years
13	15	Perineum	Excision 3 times in 19 years	Unknown after 2 years
14	32	Calf	Excision 3 times in 7 years Thigh amputation	Died of metastasis 9 years after onset
15	47	Ankle	Excision 4 times in 3 years Thigh amputation	Died of metastasis 3½ years after onset
16	43	Popliteal space	Excision twice in 5 years	Died of metastasis 9 years after onset

had multiple recurrences. Two patients underwent amputation through the thigh after local excision of recurrent tumors; both died of metastasis. In one case amputation was performed primarily because of the size of the tumor (thirty-four by twenty-nine by eighteen centimeters); the patient is known to have been in good health for twenty-one years. Only one patient of eight treated by local excision has been free of recurrences; he had been without recurrence for four and a half years at the time of the last examination. This period is not long enough for the patient to be considered cured. All of the myxosarcomata occurred in the pelvic region or the lower extremities. The majority of the tumors were first noted in the fourth or fifth decades of life. In addition to the treatment listed in Table II, several patients received roentgen irradiation without permanent benefit.

One vascular myxoma was considered to be of intermediate type (Table I).

COMMENT AND SUMMARY

In a group of fifty possible myxomata of the soft tissues of the extremities, sixteen were considered histopathologically to fulfill Stout's criteria for the diagnosis of myxoma. Fifteen of the sixteen fell into one of two groups. The main distinguishing features of the two were the arrangement of the silver-staining fibers and the vascular pattern. Tentative histopathological grouping into myxoma and myxosarcoma was made by utilizing these features. Correlation of the clinical course with the two histopathological groupings justified the histopathological diagnoses. Tumors which histopathologically were myxomata were clinically benign; those which histopathologically were myxosarcomata were capable of metastasizing. Local excision of myxomata appeared to be adequate treatment. Experience in this small series suggested, however, that in cases of myxosarcoma more radical excision and even primary amputation, after biopsy, is justified by the clinical course of this lesion. It seems likely, therefore, that the growth potentialities of myxomata and myxosarcomata can be foretold, and that clinical prognosis can be given on the basis of histopathological examination.

1. STOUT, A. P.: Myxoma, the Tumor of Primitive Mesenchyme. Ann. Surg., **127**: 706–719, 1948.

TRANSPLANTATION OF HAMSTRING TENDONS TO FEMORAL CONDYLES IN ORDER TO IMPROVE HIP EXTENSION AND TO DECREASE KNEE FLEXION IN CEREBRAL SPASTIC PARALYSIS

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The endeavor to correct knee and hip flexion in a person afflicted with cerebral spastic paralysis in order to permit an improved walking gait has always been a difficult procedure. The extension of the knee joint has been improved by division of the patellar retinacula, but when the knee joint alone is corrected, the patient continues to have hip and knee flexion in the dynamic walking gait. He may stand reasonably well, but he flexes the hip in walking; and this results in compensatory knee flexion. To improve the walking posture, improvement of both knee extension and hip extension is required.

The hamstring muscles, which are inserted into the medial and lateral tibial condyles, are strong flexors of the knee joint. In the erect walking position, they flex the knees; and to maintain balance, the patient must flex the hips. Thus, the improvement of knee extension must be accompanied by improved hip extension.

To better the gait of the patient with cerebral spastic paralysis, knee extension must be improved and hip flexion must be relieved; if any talipes equinus is present, it must be corrected.

The knee extension can be improved by the division of the patellar retinacula which permits the quadriceps femoris to act on the tibia.

The hip flexion can be relieved by the procedure of transplanting the tendons of the semimembranosus, semitendinosus, gracilis, and biceps femoris to the respective posteromedial and posterolateral sides of the femoral condyles. The contraction of the hamstrings after transplantation acts to extend the hip and indirectly to retain extension of the knee (Fig. 1). This force favorably influences the walking gait because the hamstrings do not flex the tibia at the knee joint.

Recurvature of the knee joint after

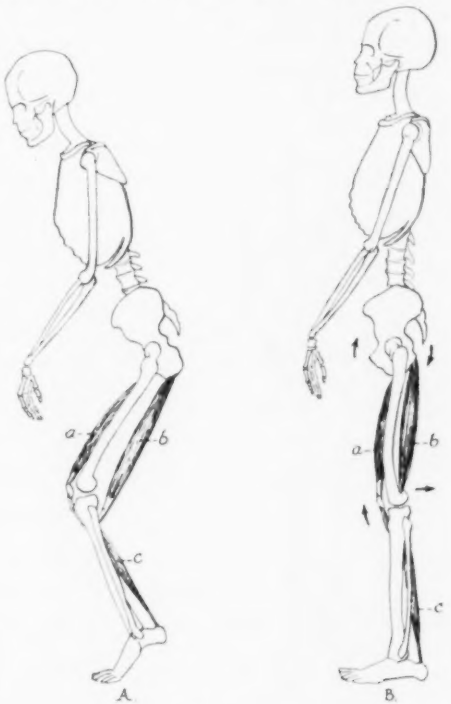

FIG. 1

A: Diagrammatic representation of the effect of overacting hamstrings on the tibia in dynamic walking gait. The knee and hip are flexed. The crouched position is due to the hip and knee flexion. To correct the flexion is the fundamental purpose, if the walking gait and posture are to be improved.

B: Diagrammatic representation of hamstrings transplanted to the femoral condyles. The hamstrings no longer flex the knees and the quadriceps, released from the retinacula, extends the knee joint. With the knee extended, the transplanted hamstrings rotate the pelvis, extend the hip, and permit a more erect posture. The heel is placed in an improved walking position.

a: Quadriceps femoris muscles. *b:* Hamstring muscles. *c:* Soleus muscle.

Fig. 2: Diagram shows the position of the lateral incisions for: *a*, Patellar retinacula; *b*, Hamstring release and transplantation to femoral condyles; and *c*, Soleus neurectomy.

FIG. 2

hamstring transplantation is prevented by the popliteus, gastrocnemius, and sartorius muscles which must not be disturbed from their normal anatomical positions, because of the danger of interfering with their nerve supply or function.

Should any of the hamstrings be required for knee support because of a postoperative knee recurvature, the tendons can always be recovered from the femoral condyles and placed in their former positions. Therefore, by transplanting the hamstrings, one loses nothing and may gain a great deal. We have never had to replace the tendons because the gastrocnemius, popliteus, and sartorius muscles have been retained in their activity.

The incisions for the hamstring transplants are on the medial and lateral sides of the knee-joint area with the patient in the prone position. The lateral incision (Fig. 2) is made over the biceps tendon about three inches long with the ends curved to

FIG. 3

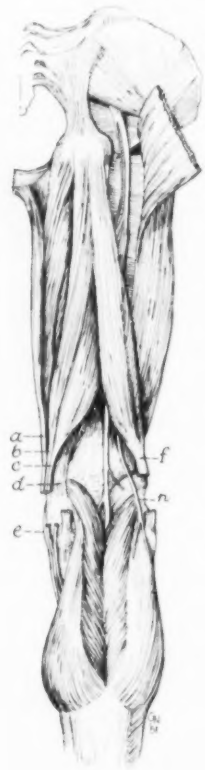

FIG. 4

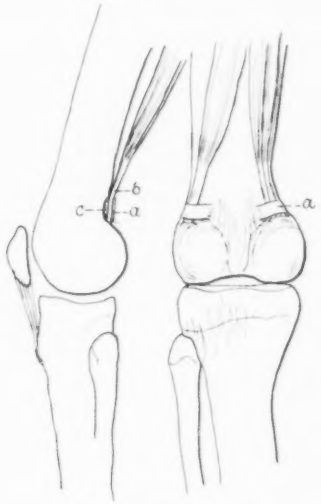

FIG. 5

Fig. 3: Diagram shows the anatomy of the tendons, muscles, and nerves involved in the transplantation of the hamstring muscles.

a: Gracilis. *b*: Semitendinosus.
c: Semimembranosus. *e*: Sartorius.
f: Biceps femoris. *n*: Common peroneal nerve.

Fig. 4: Diagram shows the division of tendons.

a: Gracilis. *b*: Semitendinosus.
c: Semimembranosus. *d*: Adductor magnus (not divided).
e: Sartorius (not divided). *f*: Biceps femoris.
n: Common peroneal nerve.

Fig. 5: Diagrammatic representation of subperiosteal placing of divided tendons. The subperiosteal groove is made with a small gouge and frequently the periosteum tears, but the tendon must rest in the osseous groove. The tendon end is sutured to the adjacent fibrous structures which are adequate.

a: Periosteal flap. *b*: Tendon. *c*: Osseous groove.

FIG. 6

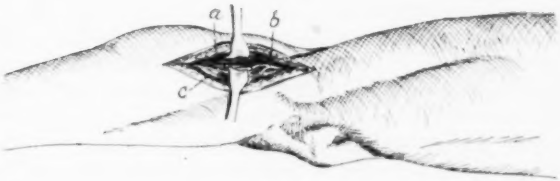

FIG. 7

Fig. 6: Diagram showing the medial incisions: *a*, Patellar retinacula and *b*, Hamstring transplantation.

Fig. 7: Diagram shows the incision for soleus neurectomy on the lateral side of the leg.
a: Gastrocnemius muscle. *b:* Nerves (proximal) to soleus muscle. *c:* Soleus muscle.

Fig. 8: Diagram shows the insertion of nerves into the soleus muscle.
a: Tibial nerve. *b:* Proximal and major branches to soleus. *c:* Small distal branch to soleus (not divided in soleus neurectomy).

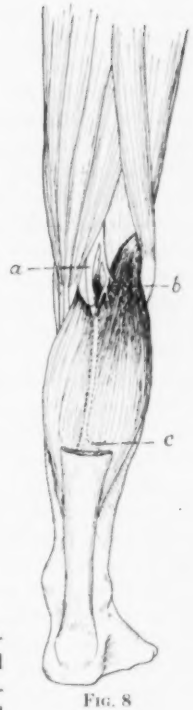

FIG. 8

prevent scar tension. The distal end is curved anteriorly just proximal to the head of the fibula. The biceps femoris tendon is exposed and identified (Fig. 3). The common peroneal nerve must be recognized and carefully preserved. The tendon is divided at the level before it bifurcates for insertion into the fibula (Fig. 4). The tendon is then placed proximally in the subperiosteal groove on the posterolateral margin of the condyle. Silk sutures are used, and there is sufficient fibrous tissue for secure anchorage. In making the subperiosteal tunnel, one may divide the periosteum. This is not important, but it is necessary that the medial side of the tendon rest in the groove, so that eventual union is with the osseous portion of the condyle (Fig. 5).

The medial incision is made posterior to the sartorius muscle or it may be made to follow the tendons from the medial condyle to the tibial insertion (Fig. 6). The ends are curved to prevent scar tension in knee motion. The semimembranosus, semitendinosus, and gracilis are divided about one-half inch from their insertion (Fig. 4) and placed in the subperiosteal groove. The divided ends are sutured to the fibrous tissue on the posteromedial side of the femoral condyle, and the tendons rest on the exposed bone of the subperiosteal tunnel for secure fixation.

The knee joint is immobilized in extension in a cast or splint for three weeks postoperatively to allow proper healing.

The incisions and the release of the patellar retinacula have been described in the presentation of the procedure previously published.[2]

Talipes equinus is seldom present in the type of case in which the retinacular release and hamstring transplantation to the femoral condyles are done. If talipes equinus is present, a soleus neurectomy through a lateral incision is the treatment of choice, with or without a heel-cord lengthening, as the case demands. However, we prefer to postpone the soleus neurectomy and tenoplasty of the heel cord because, in many cases, as walking improves, the procedures become unnecessary; and the retention of the soleus stabilizes the ankle. After a soleus neurectomy, it is very seldom that a tenoplasty of the heel cord

is necessary. The lateral approach to the nerve to the soleus is preferred, because the scar is not in a position to rub against furniture and to result in keloid formation or recurrent scar ulcerations.

The incision for the soleus neurectomy is on the lateral side of the leg posterior to the fibular margin, starting at the neck of the fibula and proceeding distally about four inches (Fig. 2). The author prefers the prone position for the execution of the soleus neurectomy. The ends of the incision may be curved. In the proximal portion of the incision, it is best to identify and to protect the peroneal nerve. The interval between the gastrocnemius and soleus is identified, and the muscles are separated (Fig. 7). A deep retractor is placed and the gastrocnemius muscle is lifted posteriorly; this allows one to see the posterior surface of the soleus muscle. In the proximal area and on the proximal medial side of the muscle, a triangular fatty mass is seen; in it are the main muscular branches to the soleus muscle and usually a small vein. The nerve can be traced into the soleus muscle and generally has two branches which may or may not have a single proximal trunk. After the two branches have been identified, they are divided and the wound is closed. The lateral approach is not difficult, and the scar is so placed as to receive no trauma. A small branch of the posterior tibial nerve in the lower half to the soleus muscles is not divided. It is small and cannot be seen by the incision described above (Fig. 8).

The combination of retinacular release at the knee joint and hamstring transplantation to the femoral condyles has been of great assistance in improving walking by improving knee and hip extension in selected cases of cerebral spastic paralysis. The transplanted tendons do not change the normal effort of the muscles involved. The patient is not required to alter the synergistic effort of the muscles because the flexors continue to function in flexion activity and extensors in extension.

The usual movements are difficult for the spastic patient to perform and to expect the patient to alter the effort of muscle function—that is, to make flexors extend or extensors flex—is a more complicated request than the affected person can accomplish. The procedures described permit the normal dynamic sequence demanded of the musculature.

The surgery must be followed by walking instructions, because the patient is unaccustomed to the new walking posture. The best results are probably apparent about one year after the surgical procedures. When evaluating the final result, one must remember, however, that the patient is still spastic.

The author recommends that the release of the patellar retinacula not be done unless the hamstrings are transplanted to the femoral condyles; however, if the hamstring tendons are transplanted, the patellar retinacula must be released. These procedures must be treated interdependently in order to secure a satisfactory result.

Transplantation of the hamstrings to the femoral condyles has been used in conjunction with the retinacular division at the knee joint since 1943. Improvement in walking has resulted in forty cases evaluated since that time. The retinacular release without transplantation of the hamstrings is not considered adequate for good dynamic function, and the cases in which the hamstrings were divided or lengthened were not as satisfactory as those in which hamstring transplantation was performed.

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PSORIATIC ARTHRITIS

Observations on the Clinical, Roentgenographic, and Pathological Changes *†

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Although the association of psoriasis with joint changes had been mentioned occasionally before, the first to pay much attention to the matter was Charles Bourdillon who, in 1888, wrote his doctor's thesis entitled "*Psoriasis et arthropathies*" [4]. When it is remembered that he worked before the roentgenogram was available and in a period when there was no clinical distinction between rheumatic fever, rheumatoid arthritis, degenerative arthritis, and protruded intervertebral discs, it is clear that his observations were indeed acute. It is clear also that, of the thirty-six patients whom he reported, the twelve or so in whom the changes were largely limited to the distal joints of the hands and feet and whom he designated as having partial arthropathies, probably represented the same disorder with which this paper is concerned.

Since that time there have been numerous reports published in French and in German but very little in the British and American literature. The paucity of careful studies is striking, especially as concerns pathology. In this field there are available two papers, and only one of these, the work of Bauer, Bennett, and Zeller [2], deals unquestionably with psoriatic arthritis. The majority of references are to single case reports, and the discussions of these usually center around the question of whether psoriatic arthritis is to be distinguished from rheumatoid arthritis. As a rule the consensus is that such a distinction is unwarranted[1,8,11]. It is the thesis of this paper that such a distinction is possible and that psoriatic arthritis is a definite clinical entity.

It has been contended by most of those who regard psoriatic arthritis as a distinct disease that the affliction is more common in males[1,12]. Although this group includes only fifteen patients, nine of them are males. This series does not include any patient in whom the diagnosis was questionable nor any patient who appeared to have the coincidental association of rheumatoid arthritis and psoriasis. The diagnosis of cutaneous psoriasis was confirmed by the dermatologists with the aid of skin biopsy.** The skin manifestations ranged from a few small and hardly noticeable patches to extremely severe and almost generalized involvement. Both dry and exudative varieties were seen, sometimes at different times in the same patient.

In the majority of patients, there was an interval of several years between the onset of the skin changes and the appearance of joint symptoms, but in two patients the joints and the skin were affected simultaneously. No patient who had true psoriatic arthritis had joint involvement of this type prior to the appearance of the skin disorder. In all patients, disease of the nails was present before arthritis appeared.

During exacerbations of the arthritis many patients had severe transient migratory pains and aches in several joints, particularly in the spine. However, the clinical and x-ray manifestations in all cases but two were limited to the hands, wrists, and feet with the major changes in the distal joints. One man had had a typical spondylose rhizomélique beginning forty years before the psoriatic arthritis, and another man had had degenerative arthritis of the spine for many years.

The initial symptoms in a given joint may be insidious in onset, but occasionally are

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** Under the direction of Dr. Stephen A. Rothman, whose constant cooperation is gratefully acknowledged.

sudden and acute. In the latter case a finger or toe can swell up in a few hours, become tense, livid, and shiny, and simulate the clinical appearance of gout (in seven cases in which the serum uric-acid level was measured, it was within normal limits). Once established, the joint syndrome tends to evolve in attacks with spontaneous remissions. In the beginning the joints may return to normal between attacks, but later there is almost always some permanent residual damage. In most patients there was no correlation between the severity of the skin disease and the severity of the joint involvement, nor were their exacerbations and remissions simultaneous. This is at variance with the majority of reports in the literature [5,6,12]. It was striking that in all cases the involvement of the joints of fingers and toes corresponded most closely to the involvement of the nails, contrary to the opinion of some observers [6]. All patients had pain and several were completely disabled.

When the disease was active, all patients exhibited an elevation of the sedimentation rate; this was the only evidence of constitutional involvement. All other laboratory tests including serum-protein levels and albumin-globulin ratio were normal except for occasional slight alteration of the lipids and cholesterol such as is said to occur with psoriasis [10]. No patient had fever, leukocytosis, or lymphadenopathy. Even the most severely afflicted patients showed an asymmetrical pattern of involvement and none showed the "rheumatoid" ulnar deviation of the hand nor any significant atrophy of skin or of the intrinsic muscles. No patient had iritis or cardiac changes and in no case were subcutaneous nodules demonstrated. The last observation, even in such a small series, is of considerable interest, inasmuch as many students of joint disease consider the subcutaneous nodule as the most characteristic single lesion of rheumatoid arthritis [3]. It is also estimated that such nodules occur in about 20 per cent. of patients with rheumatoid arthritis, while psoriasis is associated in some three per cent. [1,3]. Therefore, if rheumatoid arthritis and psoriatic arthritis were identical in etiology, one would surely expect to see psoriatic arthritis accompanied by subcutaneous nodules; but such is not the case. It is also noteworthy that, although many joints may ultimately be involved, it is not so in the early stages. Characteristically the disease progresses joint by joint, so that it is not until the later stages that the term "polyarthritis" is applicable.

The roentgenographic changes are spectacular. There is usually not any great degree of bone atrophy, even when the damage is extensive. The earliest changes are seen in the interphalangeal joints and consist of marginal erosion at the very edges of the phalanges. A little later irregular destruction is apparent, extending along the shafts of the bone from the margins so that the cortex appears "scalloped" and may contain punched-out areas. It is this stage which Zellner described as "gnawing away at the ends of the bone" [12]. Still later gross destruction of the bone ends is evident, and they may eventually be so far worn away that they look as though they had been put through a pencil sharpener. There is usually little evidence of healing, but occasionally there is overgrowth at tendon insertions which produces the "cup-like" deformity noted by Bauer, Bennett, and Zeller. Occasionally also there are irregular nodules of new-bone formation near involved joints. Rarely, and much later than is the case with rheumatoid arthritis, bony ankylosis of a joint occurs. Such ankylosis was seen in two toes of one patient in this series.

In all patients the predilection for the distal joints of fingers and toes with relative sparing of metacarpophalangeal joints was noteworthy, even in patients who had involvement of the wrists. In these latter, the arthritis was usually not in the radio-navicular joint but in the radio-ulnar, and subluxation of the ulna could be demonstrated. This condition was often accompanied by tenosynovitis. In the feet the condition starts in the distal portions, but soon involves all the joints up to and including the metatarsophalangeal. Presently these joints dislocate, the phalanx being displaced dorsally and proximally, so that its proximal end comes to overlie the distal end of the metatarsal. This difference from the changes in the hands is perhaps due to the stresses of weight-bearing. Not only

is much weight normally thrown upon the metatarsal heads, but when the distal joints are disturbed, the toes are held in extension; thus the toes are spared, but the metatarsophalangeal joints are exposed to more trauma. Even when all of these joints are destroyed, the joints of tarsus and ankle remain free of disease. In two patients there was definite involvement of the knees during one or more exacerbations, and in one of these there was also invasion of the joint between the cuboid and the fifth metatarsal.

When careful pathological examination is made of the joint tissues of a patient with typical psoriatic arthritis, two facts become evident at once. As with most other "nonspecific" joint diseases, there is no pathognomonic pattern [9]. Furthermore the findings vary greatly, apparently with the evolutionary age of the lesion.

Biopsies were performed on uninvolved joints of two patients who had psoriatic arthritis and also on normal knees of three patients who had psoriasis without arthritis. In none of these was anything abnormal seen. Material from thirty-three involved joints was obtained by biopsy and also, on several occasions, from reconstructive operations necessitated by deformities, particularly in the feet.

The youngest lesions examined were in interphalangeal joints of fingers which had been affected for only two to eight weeks. At the time of operation, it was noted that the synovial membrane had the gross appearance of pale, oedematous granulation tissue and that this tissue extended out from the joint and for a few millimeters along the shaft where the bone appeared to be roughened. In these cases the cartilaginous surfaces appeared normal and there was no demonstrable pannus. The sections show a generalized chronic inflammatory process with no specific features. It is of interest that there are always a fairly pronounced oedema and considerable fibrosis, both in the subsynovial regions and deeper (Fig. 4-H).

At a somewhat later stage the changes are seen to be similar but more severe. Grossly the synovial membrane appears to be thickened and injected; and it can often be demonstrated that it has eroded away the edges of the articulating surfaces, although the remaining surfaces still are in good condition and free of anything resembling pannus. Frequently this destruction involves also the adjacent shaft and it obviously accounts for the "gnawing away" seen in the roentgenograms. Sections of this sort of lesion show less oedema and more fibrosis than in the earlier stages. In some areas there is proliferation of the synovial cells and villus formation, while in others there is only dense fibrous condensation. Both types of tissue may or may not be infiltrated diffusely with round cells or show definite foci of inflammatory cells. Although subchondral granulations do occur, they are uncommon. As a rule, there is some fibrosis and often widespread oedema of the marrow in the subchondral bone. At the joint margins a chronically inflamed fibrous tissue can be seen, which erodes cartilage, subchondral bone, and cortex quite impartially, but which does not extend across the surface layers (Fig. 5-D).

In the late stages the findings appear to vary still more, but the basic features remain the same. Operation discloses complete destruction of the joint. The articulating ends of the bone are represented by cancellous stubs, and they are embedded in thickened fibrous tissue in which there is no trace of synovial membrane. The fibrous tissue

FIG. 1-A

Case 1. Photograph of patient shows the type and extent of cutaneous psoriasis.

FIG. 1-B

Fig. 1-B: Photograph of hands shows involvement of all nails with arthritis of most of the distal joints.

FIG. 1-C

Fig. 1-C: Roentgenogram of right hand. Definite changes are minimal, but there is ragged destruction of the distal joint of the thumb, of the proximal interphalangeal joint of the long finger, and of both joints of the little finger. Note persistence of the shadow of articular cortex, and that it is being reduced peripherally. There is some proliferation about the first metacarpophalangeal joint. There is generalized atrophy.

often surrounds the shaft of the bone and may have eroded through the entire cortex. Rarely a complete bony ankylosis is seen, but subluxation or dislocation is common. Sometimes there is proliferation of bone at the margins of the destroyed joint or nearby in the soft tissues where it may form an irregular mass. Microscopic examination shows a fairly dense fibrous tissue with mild chronic inflammatory changes replacing synovial membrane and periosteum. This fibrous tissue fills up the joint space, but it does not actively erode the cartilage from above. The destruction takes place *en masse* as the granulation tissue attacking the joint margins advances toward the center. At the same time destruction of the cortex of the shaft proceeds, so that eventually the phalanx may be represented by a slender spicule of bone buried in fibrous tissue or it may disappear completely (Fig. 4-F).

The evolution of this destructive process resembles most closely the type of change seen in a neurotrophic joint. It is not sufficiently distinctive to enable one to make a diagnosis of psoriatic arthritis from the sections alone.

The treatment of psoriatic arthritis, which formerly had to depend on the empiric approach, is much more satisfactory since the advent of ACTH and cortisone. Neither of

FIG. 1-D

Photomicrograph (× 60) of synovial membrane from proximal interphalangeal joint of right little finger.

these hormones is curative but, as in the other non-specific arthritides, both do induce remissions in psoriatic arthritis. It has been our practice to begin treatment in the hospital with relatively large doses (200 to 300 milligrams of cortisone or 100 to 200 milligrams of ACTH daily). A good clinical remission is usually evidenced within two to four days and the dose is then dropped as rapidly as possible until the amount necessary for maintenance is determined. This has varied from 10 to 50 milligrams of either drug. It has been true of all patients that, although the skin manifestations respond dramatically at the higher dosage level, they do not remain controlled at lower levels which are sufficient to control the joint symptoms. Hormone therapy is, therefore, combined with the usual local applications for psoriasis.

Patients have ordinarily been maintained on drug therapy for six to ten weeks at a time, and then the drug is gradually withdrawn. With the doses employed, we have had no untoward effects.

Immediately after withdrawal of hormone therapy, there is often a period of several days to two weeks when the patient feels worse than he did before treatment; following this the symptoms usually subside. The shortest remission in this series has been six weeks and the longest six months.

It is interesting that in 1937 Grüneberg anticipated this method of treatment [7].

CASE REPORTS

CASE 1. J. McC. This white businessman, forty-four years old, had had psoriasis for five years. Shortly after its onset the second toe of his right foot suddenly became painful and swollen. He was told that he had gout and he was treated by diet and 500,000 units of vitamin D for several weeks. There was no immediate improvement (nor any untoward side effects), but gradually, over a period of about a year, the toe came back to normal. The skin lesions slowly increased in number and size and all the nails became involved. Four years later the patient awoke one morning with intense pain, redness, swelling, and stiffness in the

FIG. 2-A

Case 2: Photograph of the hands shows the gross changes in the nails with swelling of all terminal joints except that of the left thumb. All other joints appear normal.

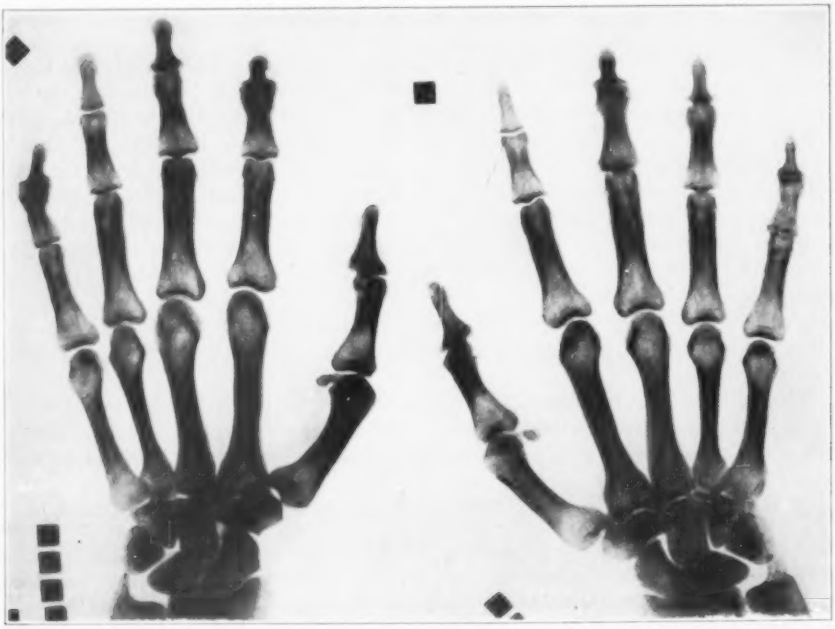

FIG. 2-B

Roentgenograms of both hands made when patient was first seen. Note gross destruction of all terminal joints except of the second finger on the right and the fourth finger on the left. All others are normal.

right ring finger. With treatment by application of heat, the finger returned to normal within two weeks. During the succeeding nine months the finger swelled again and the same symptoms appeared in the terminal

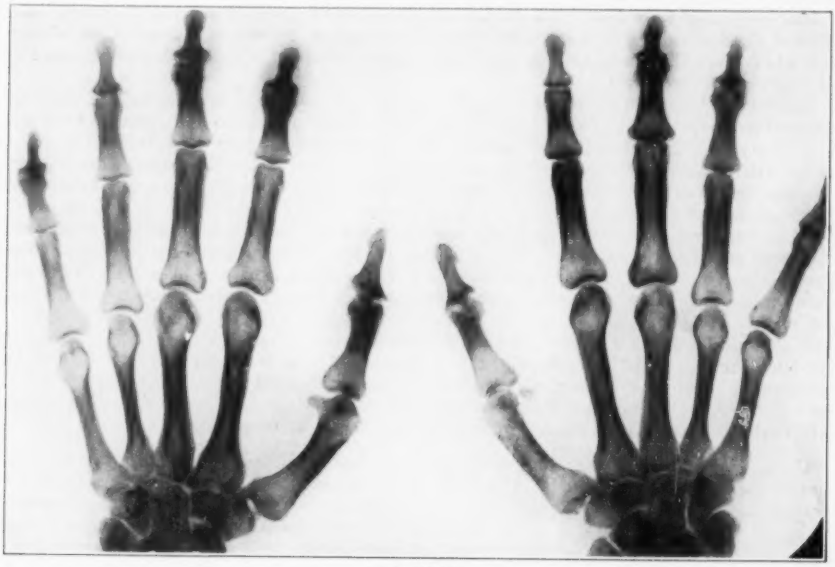

FIG. 2-C

Four years later, only the right index finger remains free. In addition there is early erosion of the proximal interphalangeal joint of the right middle finger. Note lack of atrophy.

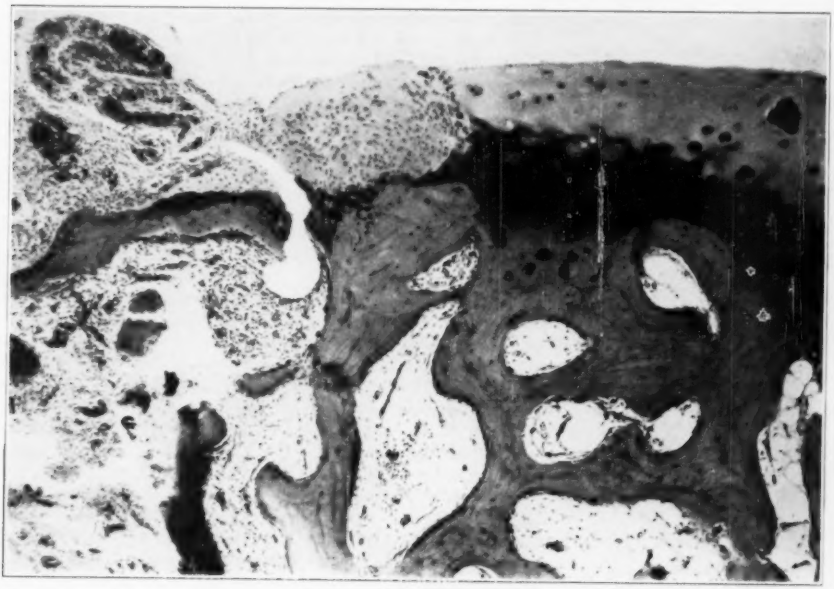

FIG. 2-D

Photomicrograph (× 60) of one edge of the terminal joint of the right thumb. Marginal erosion of bone and articular cartilage is prominent. There is no pannus and no subchondral reaction.

joints of the right thumb and little finger, the toes of the right foot, then of the left foot, and the left thumb in that order. Most recently he had had aching pain in wrists, shoulders, and neck without objective change. He had never had any constitutional symptoms except a "run-down feeling".

The condition of the patient's skin and hands can be seen in Figures 1-A and 1-B. There was limited motion of all joints and the right ring finger was stiff in extension. There were similar but less advanced changes in the feet. There were no other significant findings except that the patient looked exhausted and that he moved with great care.

Laboratory examinations disclosed only a fairly severe anaemia which responded to iron. The roentgenograms revealed a normal knee, but typical changes in the hands, most prominent about the two terminal joints of the right little finger (Fig. 1-C). It was evident that the stiffness was not due to bony ankylosis.

A few days later biopsy was made of the asymptomatic right knee and of the proximal interphalangeal joint of the right little finger. The knee joint appeared entirely normal for the patient's age, and the sections of synovial membrane, bone, and marginal articular cartilage showed only mild degenerative changes. The finger joint was grossly abnormal. Immediately beneath the extensor tendon there presented a bulging mass of thickened, oedematous synovial membrane. When this was incised, increased fluid under pressure escaped. Sections of this synovial lining showed generalized hyperaemia, oedema, and some fibrosis. There was some tendency to villus formation. There was diffuse infiltration with chronic inflammatory cells and also many focal collections (Fig. 1-D).

With general symptomatic treatment and the usual measures for the skin, the patient gradually improved, until he volunteered the information that he had not felt so well for years. In the two and one-half years since that time he has had very little trouble with his joints, but he has had three fairly severe exacerbations and remissions of his cutaneous symptoms. At present his skin is the worst it has ever been, but his joints are still well. He has permanent residual deformities in one finger and one thumb.

Case 2. J. D., a white laborer, thirty-seven years old, had had fairly severe psoriasis since childhood. When he was thirty, he had some swelling and stiffness of the terminal joint of the right long finger. Two years later the interphalangeal joints of both thumbs became involved. Four years after that the terminal joints of all fingers were affected. There were gross changes of all the nails; the patient could not give the date when these changes appeared except that he thought they appeared before the joints were attacked (Fig. 2-A). He had similar but very mild changes in the terminal joints of all toes.

Fig. 3-A

Case 3. Photograph of patient shows extent and type of cutaneous lesions. Note swollen right thumb and deformities of all toes.

General physical examination and the usual laboratory tests were normal. Roentgenograms of the hands show characteristic changes (Figs. 2-B and 2-C). In the left there is gross destruction of the terminal joint of the little finger with similar but less far advanced changes in the terminal joints of the thumb and index finger. On the right all terminal joints except that of the index finger are involved. All the other articulations appear normal. Roentgenograms made four years later show that the destruction had advanced and that all the terminal joints except that of the right index finger were now severely damaged. There was beginning involvement of one proximal interphalangeal joint.

Shortly after the first films were made the involved joint of the left thumb was operated upon. The thickened synovial membrane bulged through the capsule on the anterior surface of the phalanx, where it appeared to have eroded several pockets in the bone. There was complete destruction of the anterior portion of the articulation, but the remaining portion looked normal.

The microscopic sections show marked proliferation of the synovial membrane which is quite vascular and diffusely infiltrated with chronic inflammatory cells. Dense foci of round cells are also prominent. There is nothing resembling pannus or subchondral granulations, but impartial absorption of bone and articular cartilage is occurring at the margin of the joint (Fig. 2-D).

It was not possible to institute therapy for this patient. In the four years since he was first seen the skin condition has remained about the same, but his joints have gradually become worse. They are painful but not to the degree that one would expect from the extent of the destruction.

Case 3. H. S., a white businessman, had had rather mild psoriasis since the age of ten. When he was twenty years old, he began

FIG. 3-B

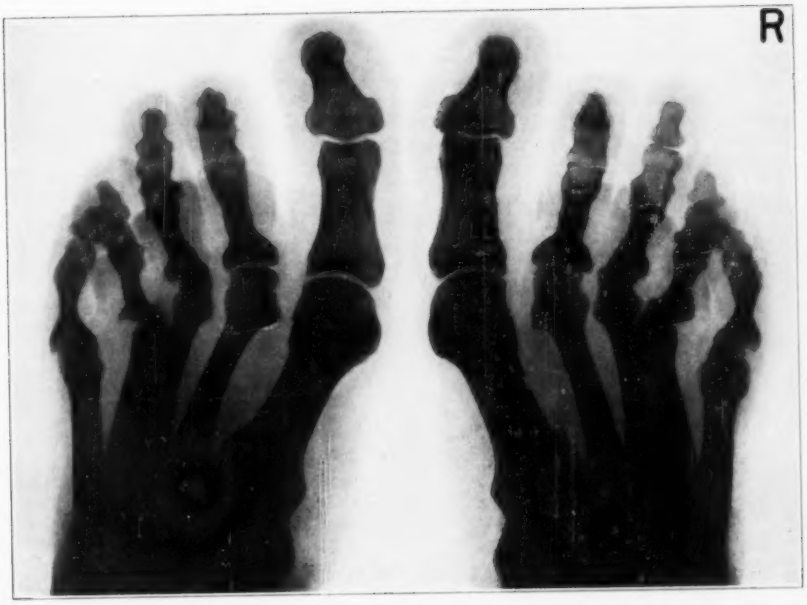

FIG. 3-C

Roentgenograms show the usual changes. Note the roughened "scalloped" cortex of shafts of proximal phalanx of right little finger and mass of irregular bone at interphalangeal joint of thumb. There are changes about almost every joint of the toes.

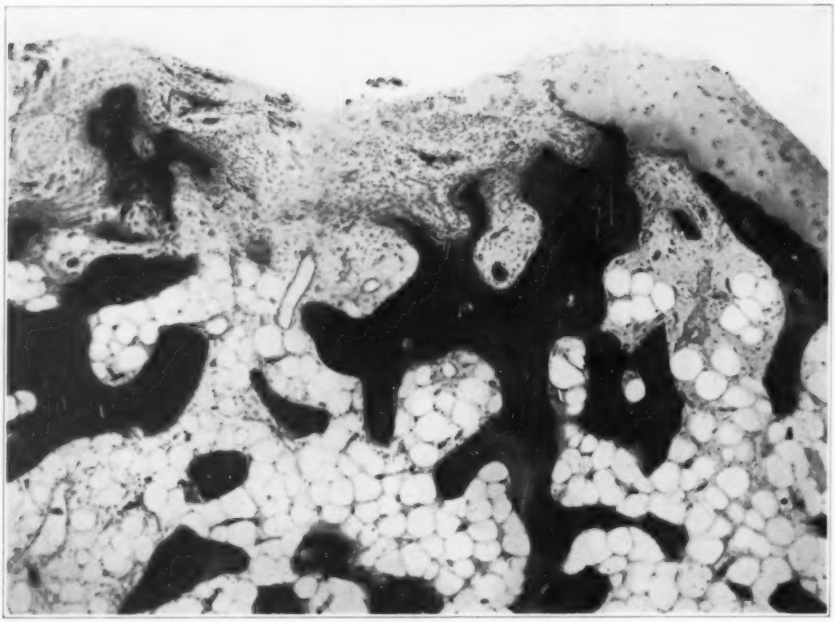

FIG. 3-D

Photomicrograph (× 60) of margin of left third metatarsophalangeal joint.

to have pain in the metatarsal region of both feet. At that time he already had changes in all the toe nails and some time later mild changes in the nails of the hands developed. Gradually the foot pain became more severe and more constant. Off and on he also had intermittent pain in his back. For this reason a diagnosis of spondylose rhizomélique had been made, and the patient had received much non-specific treatment which ranged from irradiation to typhoid therapy. By the time the patient was twenty-nine years old, he had marked stiffness and dorsal displacement of the small toes on each foot and tender swellings of the terminal joints of the right thumb and fifth finger. He was never without some discomfort in these joints, and from time to time they would swell, become red and acutely tender. The permanent changes evolved so slowly that the patient could not date them.

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 4. Photograph of patient shows skin lesions, nail changes, and swelling of terminal joints of several fingers.

Fig. 4-B: Photograph of feet shows deformities similar to those shown in Fig. 3-A. In addition, all but three toes have become much shorter than normal. Nail changes are evident in all toes.

When he was first examined by us, the patient was thirty-three years old. His complaints were limited to the pain in his feet, which were grossly deformed. All of the small toes were held in hyperextension and they were swollen. The metatarsophalangeal joints were dislocated, motionless, and acutely tender (Fig. 3-A). The terminal joints of both big toes were swollen. The right ulnar styloid was tender and the wrist slightly swollen. Both joints of the right little finger were enlarged and the motion was restricted. There was also swelling of

the proximal interphalangeal joints of the right thumb and the left fourth finger. Definite though minimal changes were present in all the nails. Of spondylose rhizomélique there was no sign. The patient had an excellent chest expansion and could easily touch his palms to the floor. In fact, his back appeared entirely normal to both clinical and x-ray examination.

FIG. 4-C

FIG. 4-D

Roentgenograms of the left hand on admission Nov. 1949 (Fig. 4-C) and sixteen months later (Fig. 4-D). Note marked progressive changes in distal joints of thumb and index finger, while the rest of the articulations remain normal and the bones are of unaltered density.

FIG. 4-E

Roentgenograms of the feet show the marked destruction of most of the phalanges and several of the metatarsal heads. There is bony ankylosis of two toes on the right foot and they maintain their normal length. The joints of tarsus and ankle are not affected.

Roentgenograms of the hands and feet disclosed the typical erosion in many joints (Figs. 3-B and 3-C).

Shortly after this time multiple phalangectomies were performed on both feet. Microscopic sections of the excised phalanx of the left second toe show the fibrous transformation of the synovial membrane which was destroying both bone and cartilage at the periphery of the joint (Fig. 3-D).

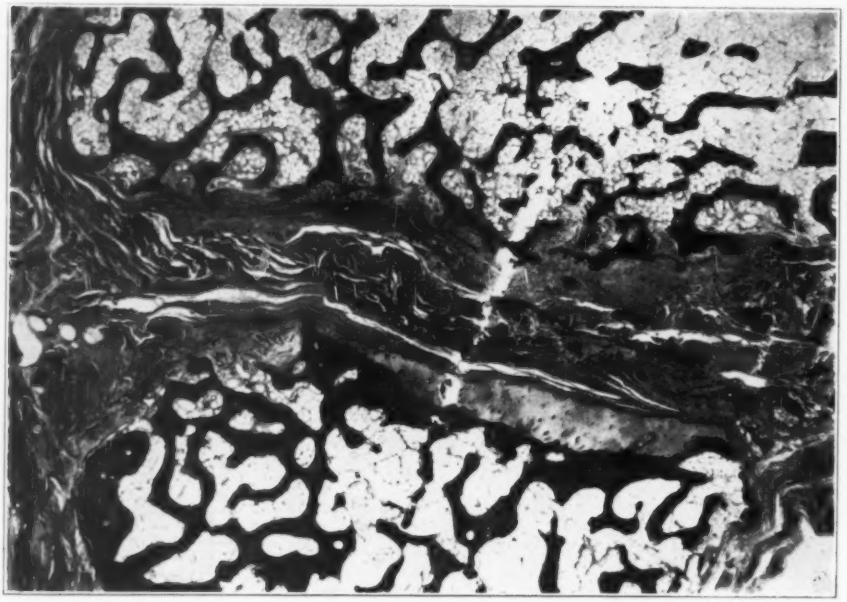

FIG. 4-F

Photomicrograph (× 17) of the left fourth metatarsophalangeal joint. Symptoms had been present for many years. Note the mature inactive appearance of the fibrous tissue which fills the joint space as well as the marginal destruction. One small bit of articular cartilage remains and it is being destroyed circumferentially rather than by active granulations above and below.

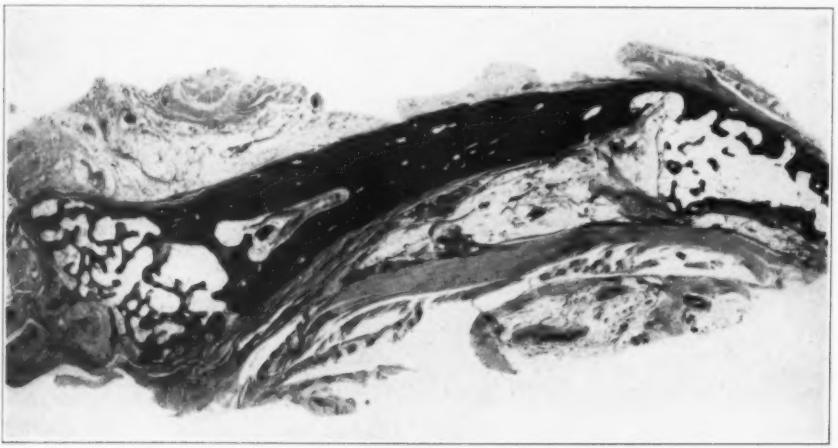

FIG. 4-G

Photomicrograph (× 6) of the proximal phalanx of the left third toe. There is no remnant of the joint and it is replaced by a mature type of fibrous tissue in which arise a few irregular trabeculae of bone. A large portion of the shaft has been absorbed.

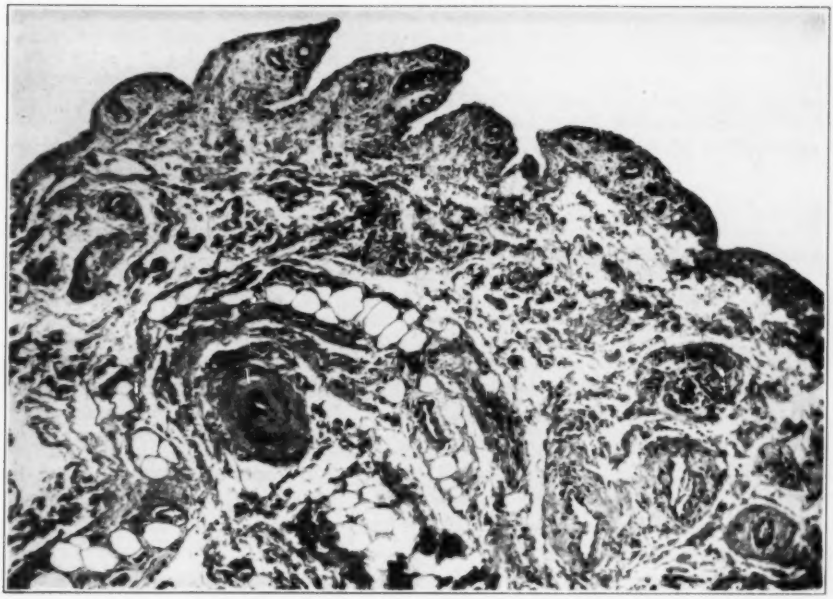

FIG. 4-H

Photomicrograph (× 105) of synovial membrane from left second metacarpophalangeal joint. Symptoms had been present for about one month. Note the oedema and fibrosis, especially about vessels. There is villus formation and slight infiltration with round cells.

The patient did well following operation until one year later, when he had an attack of back pain and sciatica which appeared to be due to a protruded intervertebral disc. The pain was relieved by a brace. One year after that, he had a severe exacerbation of pain in the hands, back, and shoulder, with moderate increase in the number and size of psoriatic patches, but no change in character. The patient noted voluntarily that back pain of this episode was different from the other. It was a vague, generalized discomfort, "more like rheumatism". The patient was treated with cortisone and an excellent remission occurred, which is still present after four months.

It is noteworthy that the pain which was thought to be due to a protruded disc was not affected by the cortisone and the patient still requires a brace.

CASE 4. W. E., a white housewife, was first seen when she was forty-two years old. Psoriasis, which had been present ever since, had developed at the age of twenty. Gradually it spread to involve most of her body, including the nails of all fingers and toes. About five years later she had had her first attack of pain in both feet with stiffness and limited motion of several of the small toes. The skin was swollen, red, and shiny. After about three days the symptoms began to subside and the feet finally returned to normal. During the next two years the patient suffered many such attacks, not all of the same severity. She was always able to get about normally during remissions, but she noted that, with each succeeding attack, the toes seemed to shrink. With the more severe attacks, she often had "neuralgia" of the back, shoulders, wrists, and elbows.

By the time she was thirty-seven this patient's feet were so distorted and painful that she had to quit work. A year later the distal joint of the left thumb suddenly swelled and became painful. Four years after that, the left index finger became affected at the time of a severe exacerbation in the toes and thumb.

The condition of the skin, hands, and feet when this woman was first seen at the University of Chicago Clinics can be seen in Figures 4-A and 4-B. The toes were all in such a degree of hyperextension that none of them touched the floor. The balls of the feet were so painful that the patient walked on her heels with the aid of a cane. The second toe of the left foot and the second and third toes of the right foot were of normal length, but the interphalangeal joints of the latter were solidly ankylosed. All the other toes were grossly shortened, thickened, and tender.

The roentgenograms show spectacular changes in all the involved joints but none in the areas afflicted by the "neuralgia" (Figs. 4-C, 4-D, and 4-E). In the left hand there is gross destruction of only the terminal

joint of the thumb. The margins of the terminal phalanx are "gnawed away". There are punched-out areas of decreased density on both sides of the joint, and the cortex of the adjacent shaft is roughened. In the feet the changes are extreme. The joints of the tarsus and ankle are normal, but all of the others have been grossly destroyed. There is bony ankylosis of the interphalangeal joints of the second and third right toes. Most of the other bones have been so reduced in length and circumference that the toes have shortened. Several of the phalanges have almost disappeared, as have the heads of the fifth metatarsals. The appearance is similar to that seen in association with neurotrophic disturbances.

Surgery was undertaken to reconstruct the deformed feet and a good result was obtained by excision of multiple phalanges and those metatarsal heads which were unduly prominent. Since that time the patient has been able to walk well, even barefoot, without support.

Sections of the material removed from the feet are striking (Fig. 4-F). Figure 4-G is a sagittal section through the proximal phalanx of the left third toe. The proximal joint surface has disappeared completely and is replaced by rather mature fibrous tissue in which arise a few trabeculae of new bone. A large portion of the shaft has also been absorbed. There is no evidence of subchondral granulations or of particular changes in the marrow spaces. There is mild chronic inflammation of the fibrous tissue.

At the same time, biopsy was made of the first and second metacarpophalangeal joints of the left hand. Both joints were filled with the usual pale, oedematous synovial membrane. Microscopic section shows early villus formation with fibrosis in subsynovial layers and about vessels, as well as oedema and infiltration with round cells (Fig. 4-H).

The patient's original surgical treatment was combined with ACTH therapy with striking benefit to both joints and skin. As was usual in this series, relatively small doses were able to control the joints satisfactorily, but much larger doses were necessary to affect the skin. In the succeeding two years one additional course of ACTH has been given. The patient has felt well most of the time and has been able to do as much work as

FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 5. Roentgenogram of the right foot made when the patient was first seen.
Figs. 5-B and 5-C are the roentgenograms made three years later at the time of surgery. Note the progression of the destructive lesions, especially the absorption of the heads of the first and fifth metatarsals. Note lack of generalized atrophy.

the average person and far more than many. However, the roentgenograms show slowly progressive destruction in the distal joints of the hands.

One of this patient's surgical procedures was done before ACTH therapy and the other at the height of the clinical response to the hormone. It is interesting that the pathological findings are not significantly different.

CASE 5. C. G., a white housewife, thirty-one years old, had a sudden onset of pain, swelling, redness, and acute tenderness in several toes and fingers. There were also "neuritic" pains in ankles, knees, and back. At the same time changes in all the finger and toe nails appeared as well as a few small psoriatic lesions of scalp and vulva. Throughout her entire course the cutaneous manifestations have never been much more extensive than this.

The joint trouble progressed steadily, but with the usual pattern of acute exacerbations and partial to complete remissions.

The patient was first seen at the University of Chicago Clinics nineteen months after the onset. She had lost twenty-five pounds and appeared frail and chronically ill. She could not get out of her wheelchair by herself and was barely able to stand with assistance. Although the patient complained of pain about the back, shoulders, and elbows, there were no findings related to these joints and no roentgenographic changes. The knees, although they appeared normal on the roentgenogram, were stiff and tender but not swollen or hot. There was marked atrophy of the muscles of both thighs and legs.

The roentgenogram of the right hand showed early changes of the characteristic type in several fingers. Figures 5-A and 5-B show destructive lesions of the toes of the right foot with preservation of the other joints of foot and ankle. The opposite foot (Fig. 5-C) and hand showed the same type of lesions.

Initially, biopsy was made of the right knee, the left wrist, and the proximal interphalangeal joint of the fourth right finger. Both of the latter joints presented the usual pale, oedematous, bulging synovial membrane which appeared to overhang and destroy the adjacent cortices. In the wrists there was a similar reaction in the sheaths of the extensor tendons. Microscopic section of this material shows again the loose, oedematous vascular hyperplasia with beginning fibrosis and with infiltration by chronic inflammatory cells (Fig. 5-D). The gross appearance of the knee joint was not abnormal, but the microscopic sections of part of the infrapatellar fat pad show a mild degree of the same sort of change (Fig. 5-E). There are interstitial fibrosis, most marked in the subsynovial layers, proliferation of the synovial cells, and a tendency to villus formation. In the deeper layers there is fibrosis about vessels.

Following the biopsies, the patient was treated with nonspecific supportive measures, and she improved until she was able to do all her own housework. She did not return to normal, however, and during the next two years she continued to have bouts of pain, swelling, and tenderness in one or another joint from time to time. In the third year she grew gradually worse, until she was again completely disabled. She had pain everywhere, and to such a degree that it took several persons to turn her in bed, but the findings (and only permanent residual damage) were still confined to the wrists and the small joints of the hands and feet. The latter were now so deformed that she had difficulty getting into her shoes.

At this time ACTH was administered with prompt and dramatic relief of symptoms. At the height of the symptomatic relief, biopsy of the wrist was repeated, and the dislocated proximal phalanges were removed from the toes of both feet.

FIG. 5-C

FIG. 5-D

Photomicrograph (× 42) of material from the distal right radio-ulnar joint. Symptoms had been present for several months and the roentgenograms showed early changes. Note the same features as in Fig. 4-H, but more pronounced.

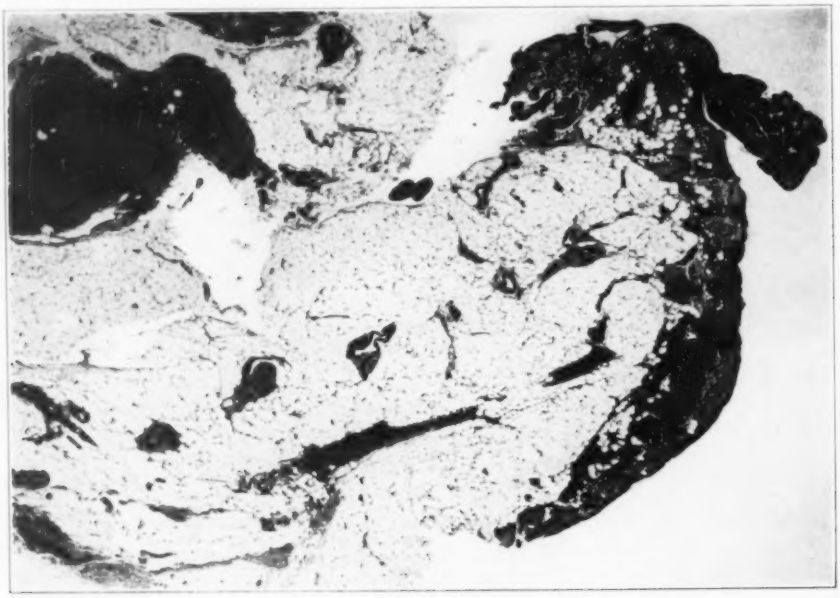

FIG. 5-E

Photomicrograph (× 19) of a portion of the infrapatellar fat pad of the right knee which had been painful for about a year. There were no findings but stiffness, and the roentgenograms were normal. However, the sections show definite fibrous proliferation in the subsynovial layer and in the deeper portions, especially about vessels. There is a tendency toward villus formation and there are focal collections of round cells.

She made an uneventful recovery from her surgery and again experienced a good remission for about six months. Then she suffered another exacerbation. She again had pain "all over", so that she was unable to move any joints freely. Even her sternoclavicular and temporomandibular joints felt stiff, but, as usual, the visible changes were confined to hands, wrists, and feet. A course of cortisone produced a remission which lasted three months; since that time the patient has been maintained on a schedule of hormone therapy for two to three months with rest periods of the same length. On one occasion, while she was taking the drug, acute pain in the left elbow developed with findings like those of an epicondylitis. This responded to novocain injection.

Throughout the entire course of this patient's disease there has never been any change in the character or extent of her cutaneous lesions. Part of this patient's surgery was done before and part after ACTH had produced remission. As in the preceding case, no difference could be seen in the microscopic sections.

CASE 6. C. S. At the age of fifteen this white boy first noted marked flaking of his scalp which was diagnosed as psoriasis. Within six months the condition had spread to include most of his skin and all of his nails and was as bad as when he was first seen at the University of Chicago four years later (Fig. 6-A).

One year after the onset of his skin disorder the terminal joint of the left forefinger suddenly swelled and became acutely painful. During the next year there followed involvement of the left first metacarpophalangeal joint, the right fifth proximal interphalangeal joint, both knees, and finally both feet. At this time, two years after the appearance of skin trouble and fifteen months after the first joint manifestation, the boy was completely disabled and had to quit work. Since then pain in his back and elbows had developed. He had at no time felt sick, but he had lost forty-five pounds; this he attributed to worry and the fact that he was so inactive. It is interesting that the patient dated the most severe exacerbation of his joint trouble to an attack of "yellow jaundice".

When he first appeared at the University of Chicago Clinics, he was a depressed and undernourished chronic invalid. There was scarcely a spot of normal skin on his body. All the nails were deeply pitted and discolored. Tender swelling and limitation of motion were present in the right elbow, both knees, the left ankle, and several fingers and toes. In addition, he had "neuralgia" of his back and shoulders.

FIG. 6-A

Case 6. Photograph of the patient shows extensive nature of his skin disease.

Roentgenograms of the spine, shoulders, elbows, and knees were normal, but the characteristic lesions were demonstrated in the hands and feet. Figures 6-B, 6-C, and 6-D show the destruction of the distal joints of the right little finger and the progression of the lesions over a period of one year. The state of the feet is seen in Figures 6-E and 6-F.

Shortly after this patient's admission, biopsy was made of the right knee joint. There was intense inflammation of the synovial membrane which was attacking the cartilage at the periphery of the joint. There were many intra-articular fibrous adhesions. About the rim of the patella there were numerous osteophytes, and the articular cartilage of the patella was softened and degenerated.

Microscopic sections of a portion of the infrapatellar fat pad show marked fibrosis, particularly in the subsynovial regions and about blood vessels. There are villus formation, proliferation of the synovial cells, and moderate infiltration with inflammatory cells (Fig. 6-G). After many types of therapy had been tried without any appreciable benefit, the patient's skin finally cleared completely following treatment with a combination of daily green-soap baths, generalized ultraviolet light, and ointments of chrysarobin, salicylic acid, ammoniated mercury, and crude coal tar. During this year there were several marked exacerbations of both joint and skin troubles and these occurred both separately and simultaneously.

Eleven months after intensive treatment was begun and at a time when the patient's skin was almost free of psoriasis, his left foot became so painful that he had difficulty putting on his shoes. The major trouble was with the base of the fifth metatarsal which protruded and was tender. The protruding portion was removed and this exposed the joint between the metatarsal and the cuboid. The surfaces of this joint were being destroyed from the margins. There was no identifiable synovial membrane and the space between the bones was filled with dense fibrous tissue. A microscopic section of this area shows only a small remnant of cartilage at one edge. Both cartilage and bone are

FIG. 6-B
Jan. 9, 1947

FIG. 6-C
Aug. 26, 1947

FIG. 6-D
Feb. 18, 1948

Figs. 6-B to 6-D: Roentgenograms of the right hand on admission, eight months and thirteen months later. Note slowly progressive destruction of the distal joints of the little finger. Fig. 6-D shows soft-tissue swelling about the terminal joint of the thumb, but there is as yet no permanent damage. The other joints are normal and there is no appreciable osteoporosis.

Figs. 6-E and 6-F: Roentgenograms of both feet. Note the typical changes of erosion and absorption with dislocation of the metatarsophalangeal joints.

Fig. 6-G: Photomicrograph (× 75) of a portion of the infrapatellar fat pad shows involvement similar to, but more advanced than, that seen in Fig. 5-E. There are the same blunt villi on a base of moderately vascular fibrous tissue. In the deeper layers fibrosis is evident about the vessels.

being engulfed by fibrous tissue which is heavily infiltrated with round cells (Fig. 6-H).

CASE 7. P. B., a retired white florist, was seen at the age of sixty. When he was fourteen years old, he had had painful swellings of both knees and later discomfort and stiffness of his back. For many years his back had been completely rigid but not painful. His knees had never been normal since the initial attack and troubled him acutely every two or three years.

When the patient was fifty-two, psoriasis developed which never involved more than a few small patches of skin at a time and was often quite unnoticeable. Shortly thereafter, the nails of all fingers and toes were affected. Two years after that, the terminal

FIG. 6-E
June 4, 1947

FIG. 6-F
Feb. 18, 1948

FIG. 6-G

FIG. 6-H

Photomicrograph (× 50) of border of joint between cuboid and base of fifth metatarsal. The only identifiable landmark is a small remnant of cartilage at lower left. Everything else has been destroyed by the fibrous tissue which is here rather heavily infiltrated by round cells. In several spots there is irregular proliferation of new bone.

FIG. 7-A

Case 7. Photograph of the hands shows gross lesions of all the nails and swelling of all ten terminal joints. The rest of the joints appear normal.

Fig. 7-B: Roentgenograms of lumbosacral spine and pelvis show obliteration of sacro-iliac joints and complete fusion of vertebral bodies characteristic of a spondylose rhizomélique. This condition had been present for thirty-eight years before the psoriasis appeared with subsequent changes in fingers and toes.

Fig. 7-C: Roentgenograms of the hands made May 27, 1949, show early destructive and proliferative changes confined to the terminal joints. The rest of the joints are normal. There is no atrophy.

joints of all the fingers and toes became swollen, red, and acutely tender. This situation had persisted for the succeeding six years but, as usual, with exacerbations and remissions.

Examination revealed complete ankylosis of the dorsolumbar spine and a right knee which was limited in motion but free of fluid. The condition of the hands is seen in Figure 7-A. The feet were in a similar state.

Roentgenograms of the spine show a picture typical of an old spondylose rhizomélique with complete obliteration of both sacro-iliac joints and fusion of the vertebral joints (Fig. 7-B). The pictures of the hands, however, show early destructive lesions in all the terminal joints without atrophy of the bones and with all the other joints intact (Fig. 7-C).

FIG. 7-B

It is believed that in this man two separate types of arthritis exist. The patient unquestionably had a spondylose rhizomélique with rheumatoid involvement of his knees

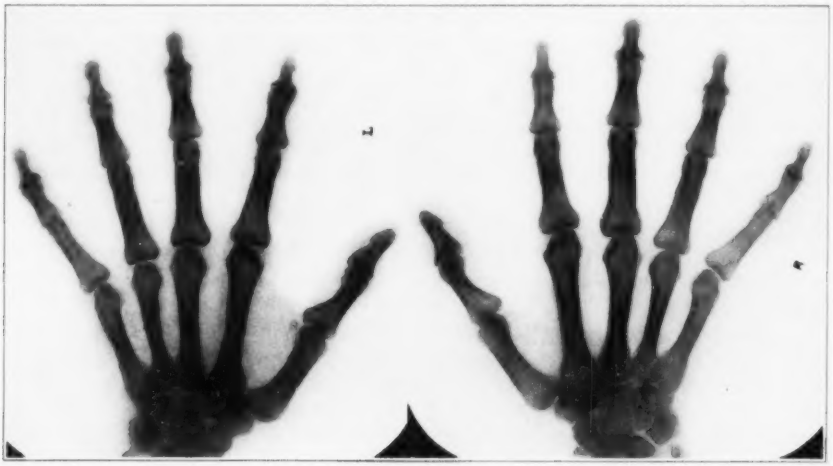

FIG. 7-C

beginning at the early age of fourteen. The clinical picture did not change appreciably until forty years later when, shortly after the onset of psoriasis, the characteristic changes in fingers and toes developed. Unfortunately this man moved across the continent and it has been impossible to follow his course.

The eight patients remaining in this series are similar to the preceding, except that the arthritis is strictly confined to the distal joints of hands and feet.

CONCLUSIONS

From the study of this group of patients, the following conclusions seem to be justified:

1. There is a type of arthritis which is peculiar to persons who have psoriasis and which has a predilection for the distal joints of hands and feet. The clinical and roentgenographic findings are characteristic and quite different from those of rheumatoid arthritis.

2. The pathological changes in this type of arthritis are constant, but are not sufficiently specific so that the diagnosis can be made with certainty from the microscopic section alone.

3. Both arthritic and skin manifestations respond to ACTH and cortisone, but the former responds to significantly lower doses. Improvement with hormone therapy is not permanent.

4. The disabling deformities of the toes can be greatly relieved by radical surgery.

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RECURRENT ANTERIOR SUBLUXATION OF THE ANKLE JOINT

A Report of Two Cases and an Experimental Study

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Recurrent subluxation of the ankle has been established as an entity in the last two decades. Roentgenographic examination of the ankle under inversion strain is now regarded as an absolute necessity for accurate diagnosis in such cases. Tilting or lack of parallelism of the articular surface of the talus in relation to that of the tibia is indicative of recurrent subluxation.

Communications on this subject present a confusing picture in regard to the comparative importance of the three components of the lateral ligament—anterior talofibular, calcaneofibular, and posterior talofibular fasciculi or ligaments—in maintaining talotibial stability. The majority of investigators on this subject believe the calcaneofibular ligament to be the most important, but they also feel that a combined rupture of this ligament and the anterior talofibular ligament usually produces the greatest degree of lateral instability [1,2,3,5,6,7,8]. Again, rupture of the anterior talofibular ligament alone has been regarded as a common lesion secondary to forcible inversion of the foot in the plantar-flexed position, but usually it is considered a simple sprain which does not produce any appreciable degree of tilting or instability. Pennal observed that division of the anterior talofibular ligament in a fresh cadaver allowed the talus to slide forward a little out of the ankle-joint mortise with inversion and plantar flexion of the foot. Leonard also called attention to such instability in the vertical axis of the talus, but associated it with a constant instability around the long axis.

The authors have encountered two cases which demonstrate appreciable anterior subluxation of the talus in the coronal plane only. In this paper, the clinical aspects and surgical findings in these two cases, supplemented by experimental work, will be reported.

CLINICAL ASPECT

Forcible inversion on the plantar-flexed foot produces a very common sprain. In such a case, the anterior talofibular ligament is most commonly injured. With the foot in equinus, the anterior fasciculus of the lateral ligament is practically perpendicular to the long axis of the tibia and consequently this component of the lateral ligament is most susceptible to injury with the ankle joint in this position.

"Chronic sprain" is the term loosely applied to persistent tenderness and swelling about the lateral aspect of the ankle joint following a previous injury. It is a condition which is a sequel to insufficient immobilization or lack of support for a proper length of time. With the advent of recurrent sprains of the ankle, the patient becomes aware of weakness, instability, and inability to run. Rising up on the toes, walking on uneven ground, and sudden forced plantar flexion of the ankle will cause pain.

When the patient is seen late, difficulty is often experienced in localizing the actual site of severest damage. Swelling may be present just anterior to the lateral malleolus. Tenderness over the course of the anterior talofibular ligament is usually present from the front of the fibula to the neck of the talus, but may be vague, owing to the protection of the extensor digitorum brevis muscle. In addition, tenderness may be found inferior to the fibular malleolus, over the calcaneofibular ligament, and even over the anterior portion of the deltoid ligament. Each of these structures shares some degree of sprain in the plantar flexion-inversion injury.

Because of its relative thinness, a complete rupture of the anterior talofibular ligament may occur with a force which would produce only a minor sprain of a stronger ligament such as the calcaneofibular ligament. Consequently, accurate diagnosis depends largely on the roentgenographic examination of the ankle joint under strain, with or without anaesthesia. Heretofore, the finding of a loss of parallelism between the articular surfaces of the talus and of the tibia in the patient seen late has been considered evidence of a recurrent dislocation.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. Anteroposterior roentgenogram made under inversion strain, while the patient was under an anaesthetic, shows normal parallelism between the articular surfaces of the talus and tibia.
Fig. 1-B: Showing downward displacement of the talus from the tibial articular surface.

FIG. 1-C

FIG. 1-D

Fig. 1-C: Lateral roentgenogram of the right ankle under strain in the coronal plane, made with patient anaesthetized. The talus is subluxated anteriorly, out of the ankle-joint mortise. There is incongruity of joint surfaces.
Fig. 1-D: Lateral roentgenogram of the opposite ankle under strain shown for comparison.

FIG. 1-E

FIG. 1-F

Fig. 1-E: Photograph of the right ankle at operation, without strain. The anterior talofibular ligament could not be identified. The lateral articular facet of the talus was exposed.

Fig. 1-F: The photograph shows subluxation of the talus with anterior strain. A portion of the posterior talofibular ligament may be seen just in front of the anterior border of the lateral malleolus. The defect in the articular cartilage is evident.

The authors' two patients had isolated ruptures of the anterior talofibular ligament with absence of tilting in one and only a slight degree of tilting in the other. Lack of response of both of these patients to conservative measures necessitated surgical repair, although most authors state that such an isolated rupture is unimportant.

CASE REPORTS

CASE 1. A male, twenty-six years old, was first seen on September 5, 1950. He had injured his right ankle on October 20, 1949, when he fell thirty feet from a bridge to a cement landing below. He was unable to recall the position of the foot at the moment of impact. Roentgenograms at that time revealed no evidence of fracture, and after three days of hospitalization he was allowed to walk with an adhesive dressing. Continued complaints had prompted the use of an Orr brace, but without benefit. His principal complaints were intermittent pain in the right ankle, a knifelike pain in the ankle when stepping on uneven ground, a sensation of weakness on plantar flexion of the ankle, and aching, usually after prolonged ambulation.

Physical examination was entirely negative except for tenderness along the anterior aspect of the deltoid ligament, as well as over the anterior talofibular ligament of the right ankle. Anteroposterior roentgenograms of the right ankle joint under inversion strain, with and without anaesthesia, however, failed to reveal a tilt of the talus in the ankle-joint mortise (Figs. 1-A and 1-B).

The patient was next seen on November 7, 1950, when it was noted that strain on the ankle joint in the coronal plane with the foot in plantar flexion produced an anterior subluxation. Manipulation of the ankle in a similar manner under anaesthesia produced definite anterior subluxation of the talus with incongruity of the talotibial joint surfaces (Figs. 1-C and 1-D).

Operation was performed on January 10, 1951. The anterior talofibular ligament could not be identified. The calcaneofibular and posterior talofibular ligaments were intact. Anterior subluxation was easily demonstrated and was found to be pronounced (Figs. 1-E and 1-F). In addition, a defect in the articular cartilage of the lateral margin of the talus was found, which had not been visualized in the roentgenogram. This defect was characteristic of an early osteochondritis dissecans. A Watson-Jones type of tenodesis was performed. Postoperative plaster-cast immobilization was continued for six weeks.

The patient resumed his work as a postal clerk on March 22, 1951, ten weeks after surgery. Five weeks later he was able to work on his feet six to eight hours a day and all complaints had been alleviated, except for some weakness when he was rising on the ball of the foot.

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 2. Anteroposterior roentgenogram of the left ankle under inversion strain in the plantar-flexed position. The slight tilt of the talus of 6 degrees indicates a rupture of the anterior talofibular ligament and the lateral capsule.

Fig. 2-B: Lateral roentgenogram made under anterior strain without anaesthesia. There is pronounced subluxation and incongruity of the joint.

CASE 2. A male, twenty-eight years old, was first seen on June 22, 1950, one hour after he had fallen a distance of eighteen inches from a trailer, sustaining a severe inversion strain on the plantar-flexed left foot. Examination revealed pronounced swelling just anterior to the lateral malleolus. Tenderness was predominantly over the anterior talofibular ligament. Roentgenograms revealed neither fracture nor lack of parallelism between the articular surfaces of the talus and tibia. Initial treatment consisted in adhesive strapping and gradual, limited weight-bearing on the affected leg with crutches. The adhesive strapping was discontinued one month later. Six weeks from the date of the accident, clinical findings were within normal limits except for slight tenderness over the anterior talofibular ligament. The patient was able to work without complaint and was therefore discharged from care.

On September 21, 1950, the patient was seen again. He complained that when he was running, playing baseball, or walking on uneven ground where the foot became plantar-flexed, he experienced discomfort in the ankle. Examination revealed only tenderness of the anterior talofibular ligament and what was thought to be a sulcus beneath the lateral malleolus on inversion of the foot. An anteroposterior roentgenogram of the ankle under inversion strain demonstrated a tilt of 6 degrees of the talus in the ankle-joint mortise (Fig. 2-A). An Orr brace with an inside upright strap and an outsi le T strap was used during the next five months, and the patient did exercises to strengthen the peroneal muscles.

However, he continued to have pain in the anterolateral region of the ankle joint. On February 12, 1951, roentgenograms were made. With the foot in plantar flexion while force was applied in the coronal plane, incongruity and subluxation of the ankle joint were apparent in the lateral roentgenogram (Fig. 2-B).

Operation on March 12, 1951, revealed a rupture of the anterior talofibular ligament. Hemosiderin deposits were found about the area of injury. The calcaneofibular and posterior talofibular ligaments were intact. Manipulation of the ankle joint revealed an anterior subluxation which was most marked when the foot was plantar-flexed. A Watson-Jones tenodesis was performed with complete correction of the instability. Postoperative plaster-cast immobilization was continued for six weeks.

The patient resumed work on May 8, 1951, eight weeks after surgery, in a limited capacity. By July 9, 1951, he was able to do heavy manual labor. Occasional discomfort was noticeable over the course of the peroneus brevis tendon which had been used to reconstruct the new ligament. He was able to run and to rise on his toes without difficulty and was most anxious to start playing baseball again.

EXPERIMENTAL WORK

The majority of authors concerned with the problem of the unstable ankle agree that a rupture of the calcaneofibular ligament gives the greatest degree of instability [1,2,3,5,6]. A combined rupture of the anterior talofibular and calcaneofibular ligaments results in

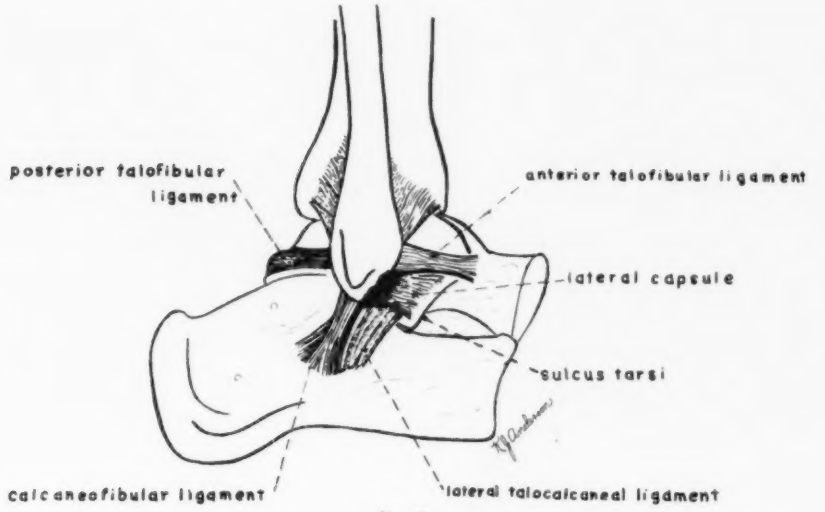

FIG. 3

Schematic drawing showing the ligaments on the lateral aspect of the ankle.

tilting of the talus in its mortise between the malleoli from 12 degrees to 30 degrees. After studying the clinical and experimental data, however, Leonard concluded that the anterior talofibular ligament was the most important component of the lateral ligament of the ankle. He found that "after the anterior talofibular ligament has been cut, the ankle is relatively stable at 90 degrees . . . [but] with the foot in equinus, there is instability in the long axis as well as in the vertical axis of the talus."

It should also be kept in mind that Berridge and Bonnin have shown that 4 per cent. to 5 per cent. of normal subjects show tilting of the talus secondary to relaxation of the fibular collateral ligament; this is the so-called hypermobile ankle.

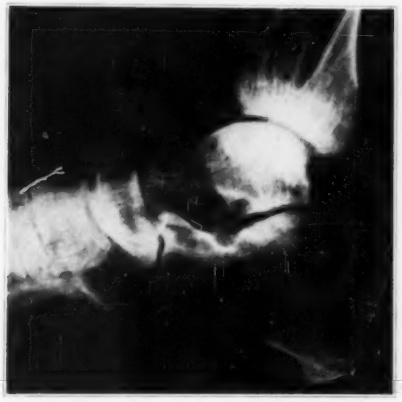

FIG. 4-A

FIG. 4-B

Fig. 4-A: Lateral roentgenogram of a preserved specimen. The metal marker in the talus has been placed in line with the anterior edge of the tibial articular surface.

Fig. 4-B: The anterior talofibular ligament has been cut and anterior force has been applied in 20 degrees of plantar flexion.

FIG. 5-A

FIG. 5-B

Fig. 5-A: There is instability in the vertical axis of the talus without instability in the long axis at plantar flexion of 35 degrees. Note the displacement of the talus away from the tibial articular surface.

Fig. 5-B: The anterior talofibular ligament has been cut. Note that the lateral capsule has been incompletely torn away from the fibular malleolus. Note also the displacement of the talocalcaneal ligament after force in the anterior plane has been applied.

The diagnostic problem of assessing the importance of the various components of the lateral ligament in maintaining stability of the ankle joint in the coronal plane necessitated experimental observations, which were made on two fresh and five preserved specimens.

Anatomical Considerations

The anterior talofibular ligament is customarily described as a weak band of fibers uniting the anterior border of the

FIG. 6-A

FIG. 6-B

The anterior talofibular and lateral capsules have been cut.

fibula with the neck of the talus. It strengthens the articular capsule laterally. Dissection study revealed the anterior talofibular ligament to be a distinct and sizeable ligament measuring from 2 to 2.5 millimeters in thickness. Overlying capsular tissue must be removed before the ligament is visualized. The calcaneofibular ligament, which is stronger, stretches from the tip of the fibula to the colliculus on the lateral surface of the calcaneus. It is the only component of the lateral ligament of the ankle which is extracapsular. The lateral talocalcaneal ligament occupies the space between these two fasciculi, running parallel with the calcaneofibular ligament. It was noted that its fibers blend not only with the calcaneofibular ligament but with the anterior talofibular ligament anterior to the lateral articular facet of the talus. In addition, lateral capsular tissue in the triangular area between the anterior talofibular and talocalcaneal ligaments appeared to blend intimately with these structures before passing beneath the calcaneofibular ligament (Fig. 3).

FIG. 7

Note defects in the articular surface of the talus produced by the anterior edge of the tibia and fibula, secondary to prolonged instability.

The course of the aforementioned ligaments varies with the degree of plantar flexion. When the foot is held at an angle of 90 degrees with the leg, the anterior talofibular ligament is parallel and the calcaneofibular ligament is perpendicular to the long axis of the talus. With the foot placed in the plantar-flexed position, the anterior talofibular ligament then is perpendicular to the long axis of the tibia and with either an inversion or additional plantar-flexion strain, the anterior talofibular ligament becomes taut.

Observations

The experimental procedure was as follows: The soft tissues were removed from the leg and foot, leaving only the ligaments and the lateral capsule intact in the five preserved specimens, while in the two fresh specimens all soft tissues were left intact except those obscuring the anterior talofibular ligament.

After the anterior talofibular ligament has been cut, the ankle demonstrates the least instability at the 90-degree position. With forward strain, anterior displacement of the talus in the ankle-joint mortise in the coronal plane amounts to about four millimeters. This is in comparison to the anatomical specimen with intact ligaments which shows an anterior displacement of two millimeters in all positions. When the ankle is plantar-flexed 20 degrees, the amount of anterior displacement increases to seven or eight millimeters. At 35 degrees of plantar flexion, there is in addition rotational displacement of the talus medially on its vertical axis, as well as the same degree of anterior

displacement. In this instance, the medial malleolus acts as a fulcrum against which the lateral aspect of the talus is levered out of the ankle-joint mortise (Figs. 5-A and 5-B). No appreciable degree of associated tilt of the talus could be produced on inversion strain when the anterior talofibular ligament alone had been cut in any of the specimens. It was noted, however, that in some specimens cutting the lateral capsule also would allow a tilt of as much as 7 degrees (Figs. 6-A and 6-B). This was not a constant finding, inasmuch as no tilt of the talus ensued after the cutting of both these structures in the two fresh specimens and in two of the preserved specimens. Chambers independently has made the same observations during his anatomical studies on the ankle. He also contends that, in the presence of a rupture of the anterior talofibular ligament, the lateral capsule, lateral talocalcaneal ligament, and calcaneofibular ligament are torn with little additional inversion force; and he wisely cautions against forcible manipulation of the ankle under anaesthesia for diagnostic purposes.

In view of the fact that an opening of the ankle joint without loss of parallelism was observed in Case 1, each specimen was manipulated in forced plantar flexion. The talus was consistently displaced downward from the articular surface of the tibia in each instance. The amount of displacement varied from four to six millimeters.

During the course of dissection of one of the preserved specimens, the anterior talofibular ligament could not be distinguished. This specimen provided the interesting finding of a defect of the articular cartilage of the talus which corresponded to the contour of the anterior aspect of the tibia. A defect was also present in the lateral aspect of the articular surface of the talus, interpreted as being produced by impingement of the talus against the anterior edge of the fibula (Fig. 7).

Finally, the calcaneofibular, posterior talofibular, and deltoid ligaments were cut separately, while the anterior talofibular ligament remained intact. Each ligament was found to have no influence on anterior instability, but the amount of lateral instability was observed to conform with that reported by other authors [1,2,3,5,6,7,8]. Angles of 15 degrees or more were produced when the calcaneofibular ligament was severed; this increased to as much as 30 degrees when the anterior talofibular ligament was also severed. Ablation of all three components of the lateral ligament rendered the ankle completely unstable.

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CLOSED REDUCTION, PLATE FIXATION, AND MEDULLARY NAILING OF FRACTURES OF BOTH BONES OF THE LEG

A Comparative End-Result Study*

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This is a comparative study of the end results of three methods of treating fresh fractures of both bones of the leg. All of these patients were treated at the St. Louis City Hospitals.

The material studied included 216 fractures of the tibia. Of these 125 were simple and ninety-one were compound. The fractures occurred in 183 tibiae; of these thirty-one were double fractures and one was a triple fracture of the shaft of the bone. There were 176 patients, in seven of whom both legs were broken. Sixty-five tibiae were treated by closed reduction under local or general anaesthesia and immobilization in a plaster cast, forty-nine were treated by plate fixation, and 102 were treated by closed reduction and fixation with a medullary nail.

The data on fractures treated by closed reduction and plate fixation were obtained from the hospital records of the years 1945 to 1948 inclusive and were follow-up records of old cases rather than new ones. Consequently, it was not possible to obtain the data on consecutive cases, because some of the records are incomplete; however, they are as nearly consecutive as possible. The fractures treated by nailing were in seventy-seven consecutive patients seen during the past three years. Most of the treatment of the patients in the first two groups was carried out by the Resident Staff, while those in the group treated by nailing were all operated upon or supervised by one of the authors; and the patients were then cared for in the Out-Patient Clinic, mostly by the Resident Staff.

The patients upon whom closed reduction was performed were treated by manipulation under general or spinal anaesthesia and immobilization in a plaster cast, or by the insertion of one Kirschner wire above the fracture site and the application of a cast or the insertion of a Kirschner wire above and another below the fracture site and the application of a cast.

In the group of patients in which a plate was employed, three types of plates were used: Lane, Townsend and Gilfillan, and Eggers. Immobilization in plaster casts was used for all patients. The plates were all inserted on the lateral aspect of the tibia beneath the muscle, and it was not noted that one type of plate was more efficient than another. In these patients and in those in the group treated without internal fixation, the casts were changed only when necessary.

The medullary nail used is one of the authors' design.[3] It is a triflanged nail made of 18-8 SMo stainless steel with a curve near each end; one flange is on the concave side. The nail is inserted just medial to the tibial tubercle through a short longitudinal incision, after a three-eighths inch hole has been drilled through the cortex at an angle of about 30 degrees. It is inserted into the drill hole with the flange on the concave side facing the crest of the tibia. The reductions and nailings were all done by the closed or blind method, except in severe compound fractures in which the ends of the fragments were exposed. In these direct vision was employed; however, after the débridement, the compound wound was not enlarged in any case in order to facilitate reduction.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 30, 1952.

TABLE I

TYPE AND LOCATION OF THE FRACTURE SITE *

Treated by Closed Reduction without Internal Fixation

	Transverse (*No. of Cases*)	Oblique (*No. of Cases*)	Comminuted (*No. of Cases*)	Total (*No. of Cases*)
Upper third	3	2	2	7
Middle third	8	17	26	51
Lower third	0	2	5	7
Totals	11	21	33	65

Treated by Plate Fixation

	Transverse (*No. of Cases*)	Oblique (*No. of Cases*)	Comminuted (*No. of Cases*)	Total (*No. of Cases*)
Upper third	1	0	1	2
Middle third	2	10	21	33
Lower third	1	10	3	14
Totals	4	20	25	49

Treated by Medullary Nailing

	Transverse (*No. of Cases*)	Oblique (*No. of Cases*)	Comminuted (*No. of Cases*)	Total (*No. of Cases*)
Upper third	2	5	10	17
Middle third	5	22	44	71
Lower third	4	5	5	14
Totals	11	32	59	102

* Of 216 fractures of the shaft in 183 tibiae in 176 patients, 16 per cent. of the patients treated by nailing had a butterfly fragment as compared to 5.3 per cent. of the patients treated by closed reduction and none of the cases in which a plate was applied. Of the fractures treated by nailing 49.2 per cent. were comminuted as compared to 37 per cent. of the cases in which closed reduction was done and 41.6 per cent. of the cases in which a plate was applied.

In the treatment of simple fractures, the nail was inserted to a point just proximal to the fracture; by mechanical traction and manual pressure the displacement was then reduced and the nail was driven down across the fracture and well into the distal fragment. The increased stability of the limb indicated that the nail had entered the distal fragment. Before the nail had been driven home, the position of fragments and of the nail were checked by roentgenograms in two planes. If these were satisfactory, the nail was driven home, the wound was closed, and the fragments were impacted by the surgeon's pounding lightly on the heel of the affected leg. The limb was then encased in a plaster cast which extended from the toes to the groin. (For four patients the cast did not extend above the knee, and in these the healing time was definitely longer than it was in similar fractures which were immobilized in the toe-to-groin cast.) At the end of the ten days, the cast and the sutures were removed, and a new long cast, fitted with a rubber heel for walking, was applied. This was worn until union was judged to be sufficiently advanced to permit full weight-bearing without the cast. The cast was replaced when necessary.

In the treatment of compound fractures, the wounds were debrided, irrigated, and closed by primary suture. After the reduction of the fracture, the limb was immobilized in a plaster cast, extending from the toes to the groin. When plates were used, they were applied after the débridement and before the closure of the wound. In the group treated by nailing, the medullary nail was inserted at the time of the débridement and closure

TABLE II

TIME IN THE HOSPITAL*

Months	Percentage of Cases: Closed Reduction Simple (*Per cent.*)	Closed Reduction Compound (*Per cent.*)	Plate Fixation Simple (*Per cent.*)	Plate Fixation Compound (*Per cent.*)	Medullary Nailing Simple (*Per cent.*)	Medullary Nailing Compound (*Per cent.*)
¼	14.3	0	9.5	0	8.6	6.6
½	14.3	8.7	0	5.2	36.9	30.0
1	25.7	17.4	28.6	15.2	26.2	23.3
2	20.0	17.4	23.9	47.4	13.1	20.0
3	5.7	21.7	14.2	10.5	4.3	10.0
4	2.8	4.3	4.7	0	4.3	10.0
5	11.4	8.7	4.7	5.3	4.3	0
6	0	4.3	4.7	5.3	0	0
6 plus	5.6	17.2	9.5	10.5	2.1	0
Number of tibiae	36	24	22	20	51	30
Average time in months	1.9	3.5	2.7	3.3	1.2	1.3

* In two weeks' time 45.5 per cent. of the patients treated by nailing were discharged as compared to 28.6 per cent. of the patients in whom closed reduction was done, and 9.5 per cent. of the patients in whom a plate was applied. In one month, 71.7 per cent. of those in whom nailing was done, 54.3 per cent. of those treated by closed reduction, and 38 per cent. of those in whom a plate was applied were discharged; in two months, 84.8 per cent. of those treated by nailing, 74.3 per cent. of those in whom closed reduction was done, and 62 per cent. of those in whom a plate was applied were discharged.

in half of the patients; in the others the cast was removed ten to fourteen days later and the wound was inspected. If it appeared to be satisfactory, the sutures were removed and the medullary nail was inserted in the same manner as in the treatment of a simple fracture.

In this series there were sixty tibiae which were treated by reduction and immobilization in a cast without internal fixation (thirty-six simple and twenty-four compound fractures). These occurred in fifty-eight patients whose ages ranged from twelve to seventy-nine years. Two young patients were included because one had a double and the other a severely comminuted fracture of the tibia. The average age, however, was forty-

TABLE III

TIME ELAPSED PRIOR TO FULL WEIGHT-BEARING IN THE CAST*

Months	Percentage of Cases: Closed Reduction Simple (*Per cent.*)	Closed Reduction Compound (*Per cent.*)	Plate Fixation Simple (*Per cent.*)	Plate Fixation Compound (*Per cent.*)	Medullary Nailing Simple (*Per cent.*)	Medullary Nailing Compound (*Per cent.*)
1	10.0	0	0	0	44.1	41.2
2	0	0	0	0	36.5	13.8
3	30.0	7.7	26.6	11.1	14.5	17.2
4	35.0	30.7	33.3	33.3	2.4	13.8
5	15.0	23.1	13.3	0	2.4	6.8
6	0	0	13.3	33.3	0	0
6 plus	10.0	38.4	13.3	22.2	0	6.8
Number of tibiae	36	24	22	20	51	30
Average time in months	3.9	6.1	5.1	5.3	1.5	2.3

* In two months 80.6 per cent. of the patients treated by nailing were allowed full weight-bearing as compared to 10 per cent. of those in whom closed reduction was done, and none of those in whom a plate was applied; in three months, 95.1 per cent. of patients treated by nailing, 40 per cent. of those in whom closed reduction was done, and 26.6 per cent. of those in whom a plate was applied were allowed full weight-bearing.

FIG. 1-A

FIG. 1-B

FIG. 1-C

A white man, seventy-two years old, had an oblique fracture of the middle third of the shaft of the tibia which was nailed by the closed method. Full weight-bearing in a walking cast was permitted two weeks after nailing; the cast was removed three and one-half months after nailing at which time full weight-bearing without support was allowed.

Fig. 1-A: Roentgenogram made before nailing the fracture of the shaft of the tibia.

Fig. 1-B: Roentgenogram made just after the removal of the cast.

Fig. 1-C: Roentgenogram made after the removal of the nail, eight and one-half months after nailing.

TABLE IV

TIME OF IMMOBILIZATION IN PLASTER

	Percentage of Cases					
	No Internal Fixation		Plate Fixation		Medullary Nailing	
Months	Simple (*Per cent.*)	Compound (*Per cent.*)	Simple (*Per cent.*)	Compound (*Per cent.*)	Simple (*Per cent.*)	Compound (*Per cent.*)
2	0	0	0	0	9.6	0
3	2.8	4.5	4.7	0	9.6	28.0
4	31.3	0	23.8	6.6	35.5	20.0
5	19.9	4.5	9.5	26.7	23.5	24.0
6	22.8	27.2	4.7	0	12.0	8.0
6 plus	22.1	63.4	57.0	66.6	9.6	20.0
Number of tibiae	36	24	22	20	51	30
Average time in months	5.7	8.4	7.3	10.5	4.4	5.1

two years. Of those in whom the fragments were fixed by plates, there were forty-two tibiae in forty-one patients; twenty of these were compound fractures. The ages ranged from seventeen to seventy-two years, the average age being forty-two. The group in which the fragments were fixed by a medullary nail consisted of eighty-one tibiae in seventy-seven patients; thirty of these were compound fractures. The patients varied in age from sixteen to eighty-four years, the average age being fifty-one years.

In these 183 tibiae, there were 216 complete fractures through the shaft of the bone. The locations and types of fractures encountered in each group are shown in Table I.

In studying these cases, we have endeavored to determine for each the time spent in the Hospital, the elapsed time before weight was borne on the extremity in the cast, the duration of immobilization in a cast, and the elapsed time before full weight was borne on the extremity, the patient walking without cast, crutch, or cane.

Time in the Hospital

The time spent in the Hospital by patients with both simple and compound fractures is shown in Table II. It will be noted that 45.5 per cent. of the patients with simple

TABLE V

TIME ELAPSED PRIOR TO FULL WEIGHT-BEARING WITHOUT CAST OR OTHER SUPPORT

	Percentage of Cases					
	Closed Reduction		Plate Fixation		Medullary Nailing	
Months	Simple (*Per cent.*)	Compound (*Per cent.*)	Simple (*Per cent.*)	Compound (*Per cent.*)	Simple (*Per cent.*)	Compound (*Per cent.*)
3	0	0	0	0	8.6	17.3
4	0	0	7.6	0	17.1	8.7
5	5.9	11.1	7.6	0	48.1	26.0
6	41.9	11.1	26.9	11.1	14.8	21.7
6 plus	53.0	77.7	57.0	88.8	11.3	26.0
Number of tibiae	36	25	22	20	51	30
Average time in months	7.2	10	10	11.8	5	6

fractures which were nailed were discharged in two weeks or less and that by the end of one month 71 per cent. of them had been discharged from the Hospital. This is to be compared with 28.6 per cent. and 54 per cent. of patients upon whom closed reduction had been done and 9.5 per cent. and 38 per cent. of those in whom a plate had been applied. At the end of two months after the injury 84.8 per cent. of patients treated by nailing,

FIG. 2-A FIG. 2-B

A white man, seventy-two years old, had bilateral tibial fractures. Both fractures were nailed by the closed method as one operation. He was put in bilateral walking casts six weeks after nailing but needed crutches for support when he walked. The cast was removed from the left limb four months after nailing and from the right, five months after nailing, at which time he was allowed full weight-bearing, using a cane for support.

Fig. 2-A: Roentgenogram of the right tibia made before the fracture was nailed.

Fig. 2-B: Roentgenogram made six and one-half months after the nailing of the fracture of the right tibia.

74.3 per cent. of those treated by closed reductions, and 62 per cent. of those treated by plates had left the Hospital.

The average time spent in the Hospital for patients with simple fractures was 1.9 months for those treated by closed reduction and fixation in a cast, 2.7 months for those treated by open reduction and internal fixation with plates, and 1.2 months for those treated by closed reduction and fixation with a medullary nail. In patients with compound fractures, the average time spent in the Hospital was 3.5 months for those treated by débridement, reduction, and immobilization in a plaster cast without internal fixation, 3.3 months for those in whom the fragments were immobilized by one or more plates, and 1.3 months for those in whom the fragments were immobilized with an intramedullary nail. In all patients with open fractures, the wounds were debrided, irrigated with salt solution, and closed by primary suture.

Time Elapsed prior to Full Weight-Bearing in Cast

In this respect there was a marked difference in favor of patients with fractures which were fixed with a medullary nail (Table III) as 44 per cent. of these were walking

FIG. 2-C

FIG. 2-D

Fig. 2-C: Roentgenogram of the left tibia made before the fracture was nailed.

Fig. 2-D: Roentgenogram made six and a half months after the nailing of the fracture of the left tibia.

in their casts by the end of the first month, 80 per cent. were walking in casts by the end of the second month, and 95 per cent., at the end of the third month. In the group of patients with simple fractures which were reduced and immobilized in a cast with no internal fixation, 10 per cent. of the patients were walking in their casts by the end of the first month; this number did not increase until the end of the third month when 40 per cent. of the patients in this group were walking in their casts. For patients with simple fractures which were plated, the time which elapsed before weight-bearing was permitted was even longer—only 26.6 per cent. of these patients in this group were bearing full weight on the extremity in the cast by the end of the third month.

The average time before full weight-bearing in the cast was allowed was 3.9 months for patients with simple fractures treated without internal fixation, 5.1 months for those who had been treated by plate fixation, and 1.5 months for those who had been treated by nailing.

As would be expected in patients with compound fractures, the elapsed time before full weight-bearing was allowed was longer than in patients with simple fractures. The figures for the three groups are shown in Table III; it will be noted that the average time was 6.1 months for patients with compound fractures who were treated without internal fixation, 5.3 for those who had been treated by plates, and 2.3 for those who had been treated by nailing.

TABLE VI

COMPLICATIONS*

	Percentage of Cases					
	Closed Reduction		Plate Fixation		Medullary Nailing	
	Simple (*Per cent.*)	Compound (*Per cent.*)	Simple (*Per cent.*)	Compound (*Per cent.*)	Simple (*Per cent.*)	Compound (*Per cent.*)
Non-union	5.6	16.0	13.0	35.0	0	0
Infection, mild	0	16.0	17.3	25.0	1.9	3.3
Infection, severe	0	8.0	8.7	10.0	0	3.3
Loss of skin requiring graft	5.6	12.5	4.3	20.0	0	0
Varus or valgus deformity	19.6	12.5	4.3	0	5.7	13.3
Shortening, more than one-quarter inch	19.6	12.5	4.3	0	1.9	3.3
Recurvatum	19.6	8.3	0	0	9.8	6.6
Offset	19.6	8.3	0	0	5.7	10.0
Rotation	2.8	4.1	0	0	0	0
Amputation	0	0	0	10.0	0	0
Thrombophlebitis	0	0	0	0	0	3.3
Number of tibiae	36	24	22	20	51	30
Average number of cases of non-union	2	4	3	7		

* Varus, valgus, or recurvatum of less than 3 degrees is not recorded in this table.

Time Immobilized in Plaster

It is again evident (Table IV) that the advantage lies with the group of patients who had been treated by nailing, for, by the end of the fourth month, 55 per cent. of

FIG. 3-A

FIG. 3-B

A fourteen-year-old white boy had a double fracture of the middle third of the tibia with a short middle fragment which was nailed by the closed method. A slight recurvatum occurred during nailing at the lower fracture site, which was not noted until several months had elapsed and which, therefore, was not corrected. In two weeks the patient was allowed full weight-bearing in a walking cast. At four months after nailing full weight-bearing without support was allowed. After union had occurred, the recurvatum caused no difficulty from either the standpoint of appearance or function.

Fig. 3-A: Roentgenogram made before fracture was nailed.

Fig. 3-B: Roentgenogram, made four months after nailing, showed recurvatum of about 5 degrees.

FIG. 4-A

FIG. 4-B

FIG. 4-C

A white man, forty-seven years old, had a compound comminuted fracture of the lower portion of the middle third of the tibia which was irrigated, debrided, and closed and an unrecognized linear fracture of the upper third of the tibia which was nailed by the closed method upon admission. During nailing displacement of the linear fracture of the upper third of the tibia occurred. Full weight-bearing in a cast was allowed at seven months; the cast was removed one month later.

Fig. 4-A: Roentgenogram made before nailing.

Fig. 4-B: Roentgenogram made after nailing showed displacement of the linear fracture, not visible in Fig. 4-A.

Fig. 4-C: Roentgenogram made one year after nailing.

TABLE VII

A SUMMARY OF THE AVERAGE TIME IN MONTHS FOR TABLES II, III, IV, AND V*

	Closed Reduction		Plate Fixation		Medullary Nailing	
	Simple (*Per cent.*)	Compound (*Per cent.*)	Simple (*Per cent.*)	Compound (*Per cent.*)	Simple (*Per cent.*)	Compound (*Per cent.*)
Time in hospital	1.9	3.5	2.7	3.3	1.2	1.3
Full weight-bearing in cast	3.9	6.1	5.1	5.3	1.5	2.3
Time in cast	5.7	8.4	7.3	10.5	4.4	5.1
Full weight-bearing	7.2	10.0	10.0	11.8	5.0	6.0

* Note how little the average time in months varied between the simple and compound fractures treated by nailing.

these were out of plaster, while in the group of patients treated without fixation and the group of patients treated by plates only 34 and 28 per cent., respectively, of these

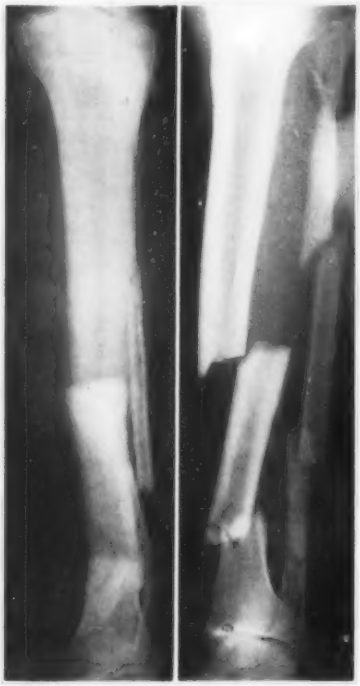

FIG. 5-A

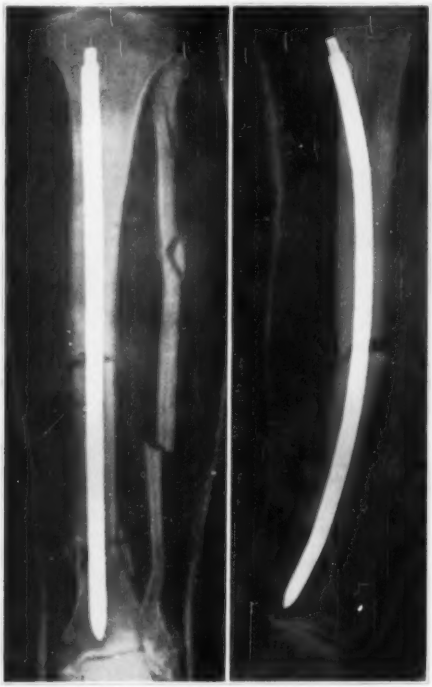

FIG. 5-B

A forty-year-old man had a compound double fracture of the middle and lower thirds of the tibia which was nailed by the closed method one week after débridement and closure. He had also sustained a transverse fracture of the middle third of the opposite femur in which intramedullary nailing was done by the open method, but not at the same time. The femoral nailing was done shortly after admission. The patient was discharged from the hospital on crutches, one month after the nailing of the fracture of the tibia. He was allowed to bear full weight on the tibia in the walking cast. The cast was removed three months after nailing and full weight-bearing on the tibia without support was allowed. Six months after nailing, the crutches were discarded and full weight-bearing on both tibia and femur was permitted.

Fig. 5-A: Roentgenogram made before nailing the fracture of the tibia.

Fig. 5-B: Roentgenogram showed a recurvatum which was corrected by manipulation *in situ* without anaesthesia at the time of the cast change two weeks after nailing. At this time a walking cast was applied.

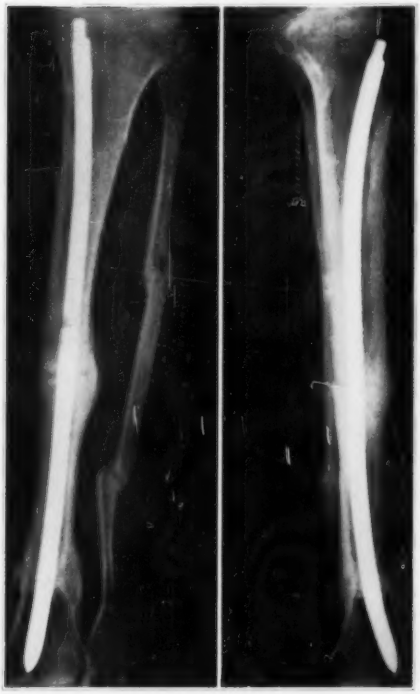

FIG. 5-C

FIG. 5-D

Fig. 5-C: Roentgenogram showed correction of the recurvatum just prior to the removal of both nails thirteen months after nailing.

Fig. 5-D: Roentgenogram made after the removal of the nail.

were out of their casts by the end of the fourth month. The average time in plaster for the three groups of patients with simple fractures was: the group treated without internal fixation, 5.7 months, the group treated by plates, 7.3 months, and the group treated by nailing, 4.4 months. In the patients with compound fractures, the casts were left on longer—for 8.4, 10.5, and 5.1 months, respectively.

Time Elapsed before Full Weight-Bearing without Support

At the end of the fifth month after the accident 74 per cent. of the patients with simple fractures of the tibia which had been nailed were bearing full weight on the leg without cast, crutch, or other support (Table V). At the same time only 6 per cent. of those treated by closed reduction without internal fixation and 15 per cent. of those treated by plating were bearing full weight on the extremity. In the patients with compound fractures the time before full weight-bearing was allowed was six, ten, and 11.8 months, respectively. The average time before full weight-bearing on the unsupported fractured extremity was five months for patients with simple fractures treated by nailing, 7.2 months for those who were treated by immobilization in a cast without internal fixation, and ten months for those who were treated by plate fixation.

Complications

Of all complications (Table VI), non-union was the most important; this occurred in six of the sixty fractures which were treated without internal fixation (two simple

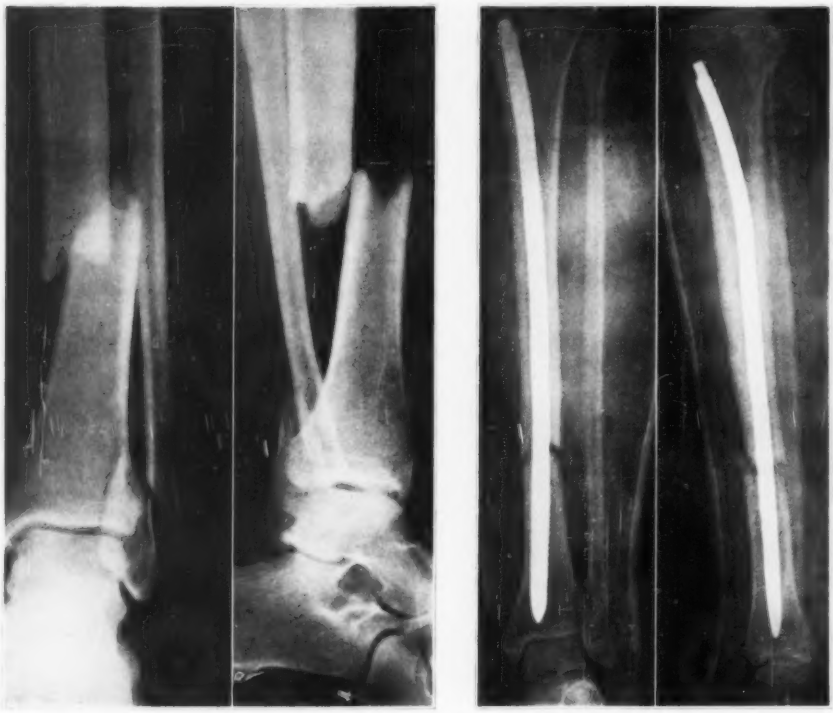

FIG. 6-A FIG. 6-B

A woman, twenty-two years old, had a compound fracture which was nailed five days after débridement and closure by the closed method. In addition to the fracture of the tibia, she had a fracture of the olecranon process and one of the surgical neck of the humerus. Five days after nailing, she was discharged from the hospital on full weight-bearing in a walking cast. At no time did she use crutches.

Fig. 6-A: Roentgenogram made before nailing the fracture of the tibia.

Fig. 6-B: Roentgenogram made after nailing showed distraction at the fracture site.

and four compound fractures), in ten of the forty-two fractures which were fixed with plates (three compound and seven simple fractures), and in none of the eighty-one fractures which were treated by an intramedullary nail. Two of the patients treated by plate fixation had the involved leg amputated, one because of infection of the leg and infection in a severe compound supracondylar fracture of the femur in the same extremity, and the other on account of the loss of blood supply to the foot below the fracture. In neither of these cases had there been an opportunity for the fracture to unite. In the latter, the plate was applied in a vain effort to save the extremity, for ischaemia was present before it was inserted.

The other fourteen fractures were in tibiae which had not solidly united one year after the accident or which had been operated upon for delayed union before the year had elapsed.

The second most important and the most regrettable complication was infection which is classified as mild or severe. The mild cases included all patients in whom the skin edges separated even for a short distance and drained for a short time. If the underlying bone was involved the infection was classed as severe; in two of the patients treated by plates the infection was severe enough to require removal of the plate and a sequestrectomy.

FIG. 6-C

FIG. 6-D

Fig. 6-C: The gap closed after full weight-bearing in the cast was permitted.

Fig. 6-D: Roentgenogram made after removal of the nail, seven months after nailing. She was allowed full weight-bearing without a cast or other support three months after nailing.

Among the twenty-two simple fractures for which a plate was applied, there occurred four mild and two severe infections; and, among the twenty compound fractures for which a plate was applied, there occurred five mild and two severe infections. Four mild and two severe infections also occurred among the twenty-two simple fractures which were treated by the application of a plate; and two mild and one severe infection occurred among the twenty-four compound fractures which were treated without internal fixation.

Of the fifty-one simple fractures which were nailed, mild infection developed in the incision medial to the tibial tubercle in one instance, but the bone was not involved and the infection subsided promptly after the wound was opened. One severe infection developed at the fracture site in one of the thirty compound fractures which were treated by nailing. In this case the nail was inserted ten days after débridement and suture of the wound in a negro woman (Figs. 7-A to 7-D). A mild infection at the fracture site was not recognized until after the nail had been driven across it. It was thus driven through the abscess and into the distal fragment. The nail was left in and the patient was treated with antibiotics. Later, the fibula was osteotomized with the result that the fracture healed and drainage ceased. She has been walking on the leg without symptoms for fourteen months; the nail is still *in situ*.

A troublesome complication was the loss of so much skin that a graft was necessary to close the wound. This occurred in a few cases in each group and was caused by the original injury. Because it was not caused by the treatment, it will not be discussed in detail here.

FIG. 7-A

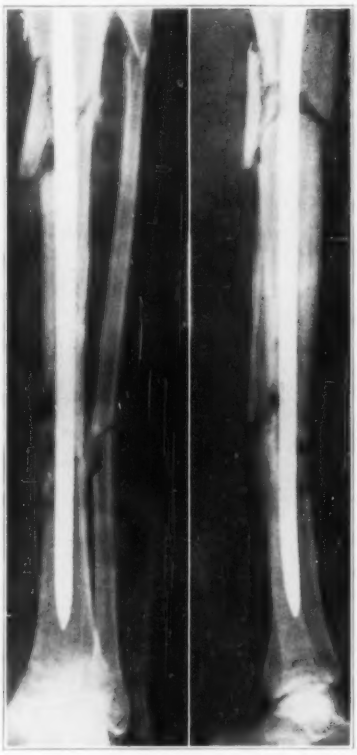

FIG. 7-B

A colored woman, forty-nine years old, had a compound comminuted double fracture of the tibia and fibula which was irrigated, debrided, and closed on admission. The fracture was nailed two weeks after débridement and closure. This became infected and resulted in a delayed union. The wound was opened and drained for about seventeen months. The wound had been infected at the time of nailing, and had been nailed through an oversight. The closed method was used. The fracture of the upper third of the tibia and the fracture of the fibula united, while absorption occurred at the site of the fracture of the middle third of the tibia. This necessitated an osteotomy of the fibula, done nineteen months after nailing. Then this fracture united.

Fig. 7-A: Roentgenogram made before nailing. Fig. 7-B: Roentgenogram made after nailing.

As is to be expected, deformities were most frequent in the tibiae which were reduced and were immobilized in a cast without internal fixation. The percentage of tibiae in which shortening, varus or valgus, recurvatum, offset deformity, and rotation deformity occurred is shown in Table VI. In many instances more than one deformity was present in a single tibia; consequently the number of bones affected is less than the number of deformities listed. The presence and severity of the deformity was determined from the roentgenograms of all of the legs. The shortening was measured from the displacement in the fibula. In no instance did it exceed one inch and in most instances it was between one-quarter inch and one-half inch. The angulation in no instance amounted to 15 degrees; in most instances it was about 5 degrees. In no instance was the deformity the cause of disability. That which occurred in the patients who were treated by nailing should have been corrected by manipulation with the nail *in situ* when the cast was changed two weeks after the insertion of the nail.

Only one case of thrombophlebitis was noted; this occurred in a compound fracture

FIG. 7-C

FIG. 7-D

Fig. 7-C: Roentgenogram, made nineteen months after nailing, showed absorption at the fracture site.

Fig. 7-D: Four months after the osteotomy of the fibula, the patient was permitted full weight-bearing in a walking cast. The gap had closed and callus was bridging the defect. Union occurred; there has been no drainage for the past fourteen months.

which was nailed. The cast was not changed; the swelling subsided; and there were no late symptoms on account of it. It is possible that other instances of this complication occurred in the series and were not recognized.

DISCUSSION

In reviewing these cases the authors are impressed with the fact that the tibiae did not unite as rapidly as did those reported in the literature. This is especially true of the time required until the patients were able to bear full weight on the leg without external support. In explanation of this it should be stated that all of these were hospital cases with severe fractures of the tibia, in which the fragments were so displaced that they could not be reduced under local anaesthesia and immobilized in a plaster cast in the Accident Room; they would not otherwise have been admitted to the wards of the City Hospitals. Fractures which can be treated in the Emergency Department are reduced and the patient is sent home in a cast; the after-treatment is carried out in the Out-Patient Clinic.

Second, a large percentage of the patients were elderly and drawn from the city's poor. It is to be expected that fractures in such a group will heal less rapidly than fractures in a group of healthy, well nourished, and vigorous young men and women.

Third, the patients often failed to return at the proper time for the removal of the casts. Consequently, in many cases the cast remained on for an unnecessarily long time. Then too, in the Clinic they were cared for by young men on the House Staff who had had relatively little experience and are taught to err on the side of conservatism. Thus it is probable that alert postoperative supervision and willingness to remove the cast and to test the leg for stability at the end of three or four months would have resulted in a lessening of the period of disability.

Finally, the time required before full weight-bearing can be permitted is a good deal longer than the time required for clinical union; about one and one-half times as long is a fair estimate. The authors were not able to determine the time of clinical union in this series of cases with sufficient accuracy to warrant a statement as to when it occurred in a given group of patients. The period of hospitalization was lengthened in some cases by other injuries to the patient or by unfavorable conditions at home which prevented proper care of the patient after discharge.

The authors were also impressed by the facts that most fractures of the shaft of the tibia can be nailed with relative ease and safety; that, if the leg is then protected with a toe-to-groin plaster cast, the patient may be able to bear weight on the extremity in the cast in a relatively short time; and that union may be expected to occur with the fragments in good position. Also union may be expected to occur somewhat sooner than if the fractures had been treated by simple immobilization in a cast without internal fixation or by plating. Oblique fractures near the ends of the bone are not suitable for nailing and are now fixed with screws. The authors believe this to be a satisfactory method of treatment for such cases in the hands of a capable surgeon. Oblique fractures in the middle third can be nailed satisfactorily; in the hands of the authors the results have been good. Otherwise, such fractures are better treated by traction or immobilization without internal fixation. The authors discourage the use of plates in any except experienced hands.

It is believed that the picture presented here represents approximately that which may be seen in most other hospitals and that disability of from five to eight months or even longer in certain severe injuries may be expected to follow a complete fracture of the shaft of the tibia with displacement of the fragments in a middle-aged man or woman. Whether or not wider use of the medullary nail will lessen this we do not know, but we believe that in proper hands it will certainly shorten the period of hospitalization, lessen the period of disability, and improve the end results in these severe injuries. However, the medullary nail should not be used casually by inexperienced surgeons; otherwise a high percentage of complications and bad results may be expected from the use of this method.

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DISCUSSION

Dr. S. Benjamin Fowler, Nashville, Tennessee: Dr. Lottes, Dr. Hill, and Dr. Key are to be congratulated on the excellence of their results obtained by medullary-nail fixation in fractures of the shaft

of the tibia. I doubt if some of their patients could have done as well by any other method of treatment. Medullary fixation has certain advantages in the management of selected fractures of the tibia which deserve recognition.

The Lottes nail appears to be an excellent instrument and its position should be established among other tested means of medullary fixation. We have not used the Lottes nail—our experience has been limited to the Rush nail and the Küntscher nail.

Our results with medullary fixation have not been so good as the authors', while our results with plate fixation have been much better than those just reported. Some of the statistics quoted, which so heavily favor medullary fixation, actually have little to do with the methods of fracture treatment.

Time spent in the hospital by these patients was not related to the healing of the fracture but was undoubtedly conditioned by other pathological conditions, the healing of the wound, the economic factors. While the loss of skin requiring a graft is stated to be due to the original injury, we note that it did not occur in the patients treated by nailing; but it was common in the patients treated by the other two methods. It is further noted that the incidence of compound fractures is somewhat less in the group treated by nailing than in the group treated by the other two means.

The incidence of reported infection in the group of patients treated by plate fixation is intolerably high and is at marked variance with our experience. Infections have apparently occurred with approximately the same incidence in compound and simple fractures. This is difficult to understand.

We do not favor the routine use of the medullary nail, rather do we feel that its use should be restricted. It is particularly valuable in the treatment of segmented fractures, and we like to use it in the treatment of patients with delayed union and non-union in conjunction with the use of autogenous strips of cancellous bone. Cortical bone has little power of regeneration in adults, and we are inclined to use cancellous-bone grafts primarily in fractures of the mid-shaft of the tibia, particularly when there is comminution posteriorly or laterally. The conservative management of tibial fractures should not, however, be abandoned. In operative cases we feel that simple screw fixation is often adequate and that in other cases the bone plate is a good method of treatment. The medullary nail has a very definite field of usefulness.

DR. RUFUS H. ALLDREDGE, NEW ORLEANS, LOUISIANA: This is a comparative end-result study, according to the authors, of three different methods of treatment of fractures of both bones of the leg.

It should be emphasized that the first two groups of cases—namely, those treated by closed reduction, and those treated by internal fixation with plates and screws—were treated by the Resident Staff in the years 1945 through 1948, while the group treated by medullary nailing were favored by being personally treated, supervised, and followed by the authors.

While the comparative results in the three groups of cases thus handled indicate that the best results were obtained in the group treated by medullary nailing and the poorest results were in the group treated by plate-and-screw fixation, it would be of great interest to know how the results would have compared, had the unsupervised residents also been responsible for the group treated by medullary nailing.

The authors have stated that they discourage the use of plates in any except very experienced hands. Yet they have compared the results in their patients treated by medullary nailing with the results of others treated by inexperienced men, so far as we can determine.

This is, however, a very complete study of a large number of cases and serves notice again that these are among the most serious injuries. The study also shows that there is room for improvement in the treatment of such fractures.

The results of the three groups of cases do not, however, prove anything definite for the reasons already stated. Possibly what is needed is as careful attention to all cases everywhere as those in this series treated by medullary nailing apparently received. It would be of great value to know the results of three similar groups of cases treated consecutively by the same high standards and by the same skilled individuals. Until a study of this type has been carried out we may not know what the best treatment is. We shall probably find that the best results will be obtained when each case is considered individually and according to the indications in the given case and not by methods of treatment, such as closed reduction, open reduction, or any other one method in all types of cases.

I want to point out that the authors have made an unusual study from a large number of cases. They have made a contribution which is very valuable. Their report is honest and complete. I rather fear that they have favored one method over all others and I feel that if they took the next seventy-five or 100 cases that came in and treated them all by either the closed reduction method or by the method indicated in each case we would probably know more about which is the best method of treatment of fractures of the tibia. I have been impressed by the apparent value of medullary fixation in the treatment of various fractures of the tibia in certain cases.

DR. KEY (closing): I do not think that I need to defend these apparently poor results, because they represent only the severe fractures from a much larger group. Simple fractures which could be reduced and immobilized in a cast were so treated and the patients sent home; only severe cases were admitted to the

(*Continued on page 882*)

TUBERCULOSIS OF THE RIB*

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Tuberculosis of the rib is a rare condition. A distinction must be made between tuberculous chondritis, involving the costal cartilage, and tuberculous osteitis, involving the body of the rib at a distance from the cartilage. It is the latter condition with which we are concerned. Tuberculosis of the costal cartilage is much more common and may result in the formation of abscesses and sinuses, as well as in the infection of the adjacent bone. Isolated, presumably hematogenous, tuberculous osteitis of the rib, particularly in the posterior portion, has been reported infrequently. A review of the American literature for the past twenty-five years reveals only two articles dealing with this subject [3,4]. Reference to a standard text[1] reveals no detailed discussion or description of this condition. The standard surgical texts and systems of surgery either make no mention of the condition or deal with it in a sentence or two. We wish to report three cases in which tuberculous involvement of the posterior portion of a rib occurred.

FIG. 1

Case 1. A roughly oval area of destruction can be seen in the juxtavertebral portion of the right fourth rib. Evidence of surgical removal of the anterior end of the right second rib is present. Both bone lesions were proved to be tuberculous by bacteriological and pathological techniques.

CASE 1. H. W., a negro male, twenty-six years old, was admitted August 24, 1948, with the chief complaint of two painful swellings of the chest wall on the right side. These had been present, increasing in size, for the past one to two months and had been associated with fever and discomfort. Upon examination, there were found two tender fluctuant masses, each measuring about ten centimeters in diameter; these were elevated about three centimeters from the chest wall. One of the abscesses was located in the right anterior infraclavicular region and the other on the right upper posterior portion of the chest wall. Pus was readily aspirated from both abscesses and revealed tubercle bacilli upon culture. A roentgenogram of the chest revealed no evidence of pulmonary or pleural disease. The increased densities due to the abscesses were visualized, as well as destructive changes in the right second and fourth ribs (Fig. 1). The fourth rib presented a roughly oval area of destruction in its posterior portion, about two centimeters from its articulation with the spine. The second rib showed destruction and widening, with some fragmentation of the cortex, at the costochondral juncture. There was no other evidence of tuberculous involvement elsewhere in the body. The treatment consisted of streptomycin, one gram daily. Both abscesses were incised and drained.

Ten days after drainage of the abscess, the anterior five centimeters of the right second rib was resected and one week later an eight-centimeter segment of the right fourth rib was resected. The pathological diagnosis of each specimen was "tuberculous osteitis". Healing was complete in both wounds six weeks following resection.

CASE 2. L. McK., a negro male, twenty-six years old, was admitted February 17, 1950, complaining of a mid-thoracic backache and of a swelling of three months' duration in the right posterior portion of the

* Reviewed in the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions published by the authors are a result of their own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 2. X-ray after instillation of iodized oil into the abscess of the posterior portion of the chest wall, secondary to tuberculosis of the right eighth rib.

Fig. 2-B: Case 2. X-ray after incision and drainage of the abscess of the posterior portion of the chest wall. Destructive changes are seen, involving chiefly the inferior border of the posterior portion of the right eighth rib.

chest. Examination revealed a mass in the right mid-scapular line, at the level of the eighth thoracic vertebra, about the size of an orange. This mass was tender and fluctuant upon palpation. Aspiration of the abscess revealed frank pus which was positive for tubercle bacilli upon smear and culture. A roentgenogram of the chest revealed no evidence of pleural or pulmonary disease. Roentgenograms of the spine were negative. An iodized oil was injected into the abscess and the roentgenograms (Fig. 2-A) showed no evidence of a paravertebral abscess. Treatment was started on February 21 with streptomycin, one gram daily intramuscularly, and para-aminosalicylic acid, twelve grams daily orally. The abscess was incised and drained April 11, 1950.

A new roentgenogram for bone detail, made on May 1, 1950 (Fig. 2-B), revealed partial destruction of the posterior portion of the right eighth rib. Rib resection was done on May 22; the surgeon removed bone from the diseased area and from two to three centimeters of normal bone on each side.

The pathologist's description read: "On splitting the rib lengthwise, in the center of the rib there was some rarefaction of the marrow. No definite abscesses could be found, nor were there areas of gross caseation.

"*Microscopic:* Section of rib reveals irregular bony trabeculations with a few areas of fibrosis and infiltration by lymphocytes, monocytes, and plasma cells. No giant cells are seen.

"*Diagnosis:* Granulomatous inflammation of bone compatible with, not diagnostic of, tuberculosis."

Streptomycin and para-aminosalicylic acid were continued until August 16, 1950. The wound was completely healed at that time. The patient at no time presented evidence of tuberculous involvement elsewhere, and he was discharged from the Hospital August 16, 1950.

CASE 3. L. McC., a negro male, thirty-three years old, was readmitted to the Hospital March 7, 1951, having been discharged with arrested pulmonary tuberculosis in September 1950. He had received pneumoperitoneum from August 1949; he had continued to receive it as an out patient. In December 1950, he had complained of pain in the right posterior aspect of the chest. Examination revealed a non-tender fusiform

FIG. 3

Case 3. Destructive changes are visible along both borders of the posterior portion of the right eleventh rib, but more marked on the upper border. An x-ray ten weeks earlier revealed this rib to be normal, even in retrospect.

deep-seated mass, about the size of a lemon, located over the posterior portion of the right eleventh rib. Roentgenograms of the ribs and spine were interpreted as negative and aspiration was unsuccessful in obtaining pus. Hospitalization was advised but was not accepted. In March 1951, when the swelling had increased in size and had become quite tender, another aspiration revealed pus which was positive for tubercle bacilli on smear and culture; the patient was hospitalized. A new roentgenogram (Fig. 3) revealed definite bone destruction of the posterior portion of the right eleventh rib. On March 9, 1951, a small pleural effusion on the right side was noted on the chest roentgenogram. This had not been present on a roentgenogram made on September 27, 1950. Streptomycin, one gram twice weekly, with para-aminosalicylic acid, twelve grams daily, was started March 13, 1951. The abscess was drained March 14, 1951, and resection of a large segment of the right eleventh rib was performed April 11, 1951.

The pathological report read: "Numerous fragments of bone and marrow are apparent. Some areas show fibrosis of the marrow. Rare giant cells are seen. No areas of caseation or necrosis are seen.

"*Diagnosis:* Chronic osteomyelitis, non-specific, of the rib."

The immediate postoperative course was uneventful. The wound healed slowly, being closed by July 1, 1951. The small pleural effusion had disappeared, as shown by roentgenogram, by July 1, 1951. However, at about this time, a new abscess developed in the right lower flank. A roentgenogram of the right ilium revealed an oval area of bone destruction about three centimeters in diameter. Aspiration of the abscess revealed thick yellow pus, which was negative on smear and culture for tubercle bacilli. This abscess was incised and drained on July 3, 1951. No direct bony communication could be felt by the surgeon. Resection of the involved portion of the ilium is planned.

DISCUSSION

As previously mentioned, tuberculous osteitis of the rib is a rare condition. Rechtman reported a single case in an infant who also had tuberculous arthritis of the knee. The abscess and the diseased rib were removed at a single operation; the wound healed completely in one month. The author found no references to this condition in the American literature and only four cases in the European literature.

Wassersug was able to cull fifty cases from the literature, all but one of which were from Europe. The large majority of these cases were tuberculous osteochondritis, involving the anterior end of the rib, a much more frequent condition. Wassersug reported thirteen cases from Lakeville State Sanatorium, but again he made no distinction between the more common tuberculous chondritis and the rarer tuberculous osteitis. Of the thirteen cases, nine had other tuberculous foci of a lymphatic or hematogenous type.

Lewin states: "Tuberculosis of the ribs is uncommon. I have seen very few cases. My recommendation for localized tuberculosis of the ribs is resection of the diseased area."

While the exact pathogenesis of these lesions is not certain, they are probably hematogenous in origin, differing in no way from tuberculous involvement of other bones. There was no evidence in any of our cases of extension from adjacent organs, and in the first two cases the involvement of bone was the only detectable evidence of tuberculosis. In each instance, the patient first noticed a swelling of the chest wall, which gradually increased in size and was associated with mild toxic symptoms. Physical examination revealed evidence of a typical cold abscess in each case; this was confirmed by the results of aspiration with the recovery of tubercle bacilli in all three patients. The only accom-

panying phenomenon was the development of a small ipsilateral pleural effusion in Case 3. In all probability, this was due to involvement of the parietal pleura by the cold abscess, although, of course, it may have been a coincidence. Roentgenograms of the involved rib in each case showed some destructive change. In Case 1, this was characterized by an area of decreased density within the rib substance, whereas in Cases 2 and 3 it consisted of osteolytic changes, involving the rib margin and eventually the rib body. These roentgenographic changes occurred rather late. In Case 1 the cold abscess had been present over the posterior portion of the fourth rib for several months before the bone lesion was discovered. In Case 2, the bone lesion was not apparent until after the incision and drainage of the abscess. In Case 3 serial x-rays were made. The first of these was made because an abscess was already present, but it failed to reveal any bone changes, even in retrospect. The bone changes were first noticed several months after the abscess appeared.

As a result of these observations, we feel that a certain reserve is indicated before ruling out tuberculosis of the rib as the cause of an otherwise idiopathic cold abscess. A comparison can be made with other types of osteomyelitis. In acute hematogenous osteomyelitis, there is a period early in the disease when the local changes (such as heat, swelling, and tenderness) are well developed, but the x-ray shows no abnormality. The changes seen on the roentgenograms in acute osteomyelitis develop within one to two weeks, while in tuberculous osteitis they may take several months.

Diagnosis and Differential Diagnosis

Tuberculosis of the rib must be distinguished from other types of inflammatory bone lesions of the ribs and from benign and malignant tumors. The cold abscesses must be distinguished from cysts and tumors of the chest wall and from the somewhat more common type of cold abscess in this area secondary to tuberculosis of the thoracic spine. The lateral location of the abscess, the results of aspiration, and the use of repeated roentgenograms of the underlying ribs will enable such a differential diagnosis to be made.

In each of our cases, an osteolytic process alone was observed on the roentgenogram. There was no evidence of periosteal activity, sequestration, or calcification. This was perhaps due to the early surgical resection, as in tuberculous involvement of other bones we have observed soft-tissue calcification and bone regeneration with prolonged conservative treatment.

Treatment

The treatment which we have found effective in these cases consists in incision and drainage of the abscess with resection of the involved bone after a short interval. While a one-stage operation might be equally satisfactory, we have advocated a two-stage procedure for the following reasons: After incision and drainage, the pus diminishes in amount quite promptly and may become sterile upon culture. It is felt that the chance of spreading the infection during the rib resection is diminished in this way. Streptomycin was used alone in one of our cases, and with para-aminosalicylic acid in the other two. Current concepts [2] would probably call for streptomycin, one gram twice a week, and para-aminosalicylic acid, twelve grams daily, starting a week or two before surgery and continuing until healing is complete. This may be anticipated in one to three months. The duration of treatment must also be governed by the presence of other tuberculous involvement. Of our three cases and the fourteen others referred to [3,4], twelve had other evidence of hematogenous or lymphogenous tuberculosis and for this condition prolonged chemotherapy or sanatorium treatment may be indicated.

Even in the presence of streptomycin-resistant organisms, it is probable that surgical excision of the involved bone is the treatment of choice. This has been successfully used by other authors [1,3,4] prior to the discovery of streptomycin.

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DISCUSSION

Closed Reduction, Plate Fixation, and Medullary Nailing of Fractures of Both Bones of the Leg

(*Continued from page 877*)

wards of the hospital. Striving to get the average city hospital patient with severe fractures of both bones of the leg up, healed, and walking in three or four months is wasted effort; it does not often happen. It can be done with mild fractures in which only slight displacement has occurred, but most of the fractures in this series were double or comminuted fractures; all were complete and were severely displaced fractures, and a lot of them were compound.

We were particularly interested in the nailing when we started to treat these fractures by this method, and we wanted to get the best results possible. We temporarily abandoned all other types of treatment for severe fractures of both bones of the leg. This was true of the compound as well as of the simple fractures. We tried nailing compound fractures on admission or as soon afterward as the Resident Staff could get to it, and we tried débridement and primary closure, doing the nailing sometime later. All fractures were closed primarily. The result was that there was only one severe infection in all of these compound fractures, which happened to be in one that had been closed and then nailed two weeks later. In fractures which were closed and nailed immediately there was no severe infection.

Of the two minor infections that occurred, one was at the nailing site and the other was at the site of the compound fracture wound. Both infections healed promptly after the wounds were opened. This indicates to me that it is perfectly feasible to nail war-incurred fractures at the time of the original débridement, at the time of the delayed primary suture, or within two weeks after that. I think, however, that it would be safer to nail them immediately than at any other time and I believe we are going to adopt this for treatment of fractures of the femur and tibia. Such a procedure as this should be done by men who are both experienced and capable, for the procedure must not be undertaken lightly. This, in spite of the fact that about 50 per cent. of our group of tibial nailings were done by the Resident Staff.

They were all cared for in the Out-Patient Clinic. Those of you who work in city charity institutions know how hard it is to get these people to come back for after-care. As a matter of fact, I think only 20 per cent. of these nails have been removed up to this time. Closer supervision would have resulted in a shortening of the period of disability. All of our fractures were reduced by closed manipulation and the nail was inserted blindly and then checked with the x-ray.

Surgeons differ in their ability to use open reduction and internal fixation and closed reduction. Witness Sherman's facility with internal fixation and the skill of Willis Campbell in closed reduction. The older men remember Willis Campbell and his ability to perform closed reductions of fractures of the femur which he immobilized in plaster spicas. I do not believe that his results have been excelled by any method. He had great natural skill at closed reduction. Other men will develop excellent technique with bone plates. It does not take long for a young man to learn to place nails well. If they do that, there will be a very much broadened field of usefulness for this method, but it must not be taken lightly.

CONGENITAL ELEVATION OF THE SCAPULA

BY CONSTANTINE L. JEANNOPOULOS, M.D., NEW YORK, N. Y.

From the New York Orthopaedic Dispensary and Hospital, New York

The clinical and morphological aspects of Sprengel's deformity and the theoretical considerations regarding the pathogenesis of this anomaly were reviewed by Horwitz in 1908. The literature on this subject is extensive; reports on the results of treatment, however, have been few and incomplete. Putti, in 1908, reported on an operative procedure which consists in detachment of the scapular insertion of the rhomboids and trapezius (lower and middle fibers), resection of the omovertebral bone when present, transplantation of the scapula to a lower level, and fixation of its inferior angle to a rib. Schrock, in 1926, described an operation which varies from Putti's in that the supraspinous portion of the scapula is resected and the scapula is released subperiosteally, prior to its transplantation to a lower level. Scaglietti, in 1935, reviewed the results in four cases operated upon by Putti and emphasized the need for early intervention to

TABLE I

ASSOCIATED ANOMALIES IN THE CERVICAL AND THORACIC SPINE AND IN THE THORACIC CAGE

	Cases	
	(*Number*)	(*Per cent.*)
Vertebrae		
Incomplete segmentation	14	40.0
Hemivertebra	9	25.7
Spina bifida	7	20.0
Ribs		
Absence, malformation, fusion of adjacent rib segments	17	48.5
Cervical ribs	11	31.4

obtain the best results. Smith, in 1941, reported on the results of various operative procedures performed on thirteen patients.

The purpose of this paper is to discuss a series of thirty-five cases observed at the New York Orthopaedic Dispensary and Hospital between 1933 and 1950 and to present a follow-up study of twenty-one patients on whom operation was performed.

There were twenty-five female and ten male patients in this series. The deformity occurred on the right side in sixteen patients and on the left in fifteen. It was present bilaterally in four.

ASSOCIATED ANOMALIES

Maffei, in 1923, observed that congenital elevation of the scapula does not exist without anatomical lesions of the vertebral system. In an unpublished series of thirty-five cases collected through correspondence, Schrock, in 1931, noted that there was no case of an undescended scapula without associated abnormalities in the cervical or thoracic vertebrae or in the thoracic cage. These observations are confirmed by the present study. Four patients in the author's series had one such osseous anomaly in addition to the undescended scapula. In one of these patients with a malformed third rib, the sterno-

costal component of the pectoralis major was absent. There were two or more anomalies in the vertebral column and thoracic cage in the remaining patients (Table I). Torticollis was present in four patients; this, however, was secondary to anatomical malformations in the cervical spine and was not caused by primary contracture of the sternocleidomastoid muscle. Asymmetry of the chest wall was a frequent finding. Twenty patients (57 per cent.) had a lateral curvature of the spine which was usually mild in character. The primary curve was cervicothoracic or high thoracic and was frequently associated

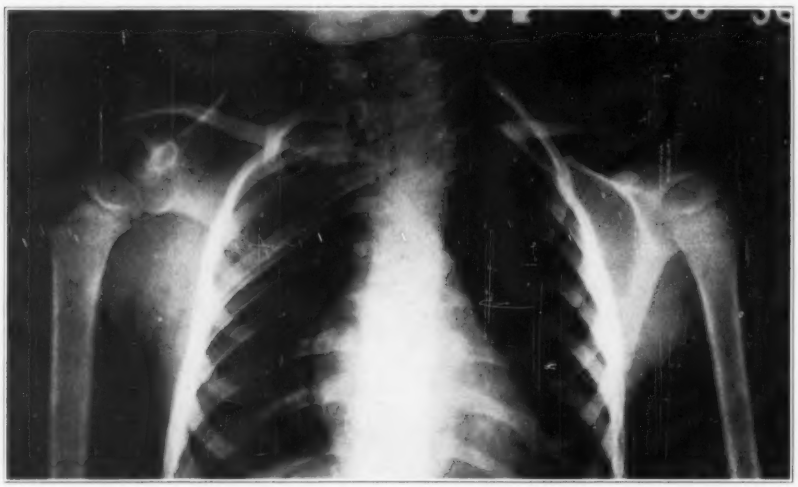

FIG. 1-A
Congenital elevation of the scapula before operation.

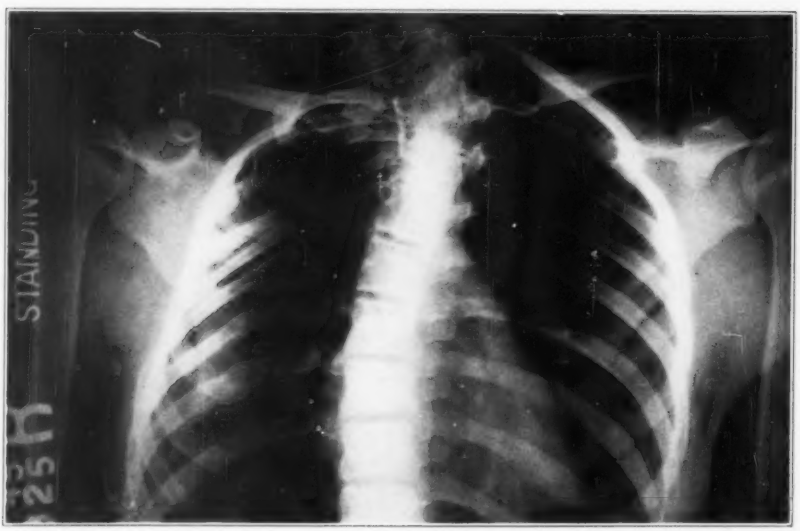

FIG. 1-B
Same patient nine years after operation. Excellent correction. Note the associated anomalies in the spine and thoracic cage.

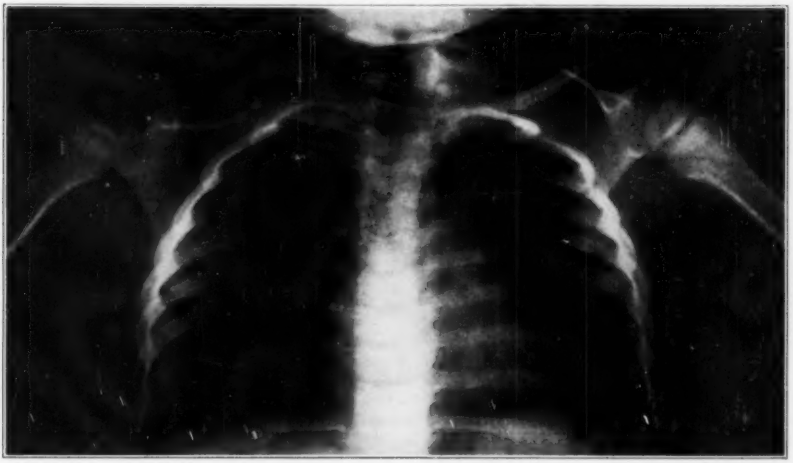

FIG. 2

Roentgenogram showing congenital elevation of the scapula with an omovertebral bone.

with hemivertebrae or incomplete segmentation of the vertebral bodies (Figs. 1-A and 1-B). There was no correlation between the severity of the scoliosis and the character of the osseous anomalies of the spine.

FIG. 3

Lateral view of an omovertebral bone, showing osseous continuity with the spinous processes of the cervical spine.

OMOVERTEBRAL CONNECTION

An omovertebral bone was present in eleven patients in this series and was excised at operation in ten. It appeared as a roughly trapezoid or wedge-shaped chondro-osseous structure, the narrow extremity of which was continuous with a spinous process, lamina, or transverse process of one or more of the lower cervical vertebrae (Figs. 2 and 3). In one patient the omovertebral bar had no bone or cartilaginous continuity with the spine. Its apex, instead, was globular or knoblike in shape (Figs. 4-A and 4-B), and was covered with hyaline cartilage; it articulated with a cervical spinous process as an enarthrodial joint. The mode of attachment of the omovertebral bar to the vertebral border of the scapula varied greatly. Bone continuity or synosteosis was noted in one patient and cartilaginous union was present in three. In one patient, the omovertebral bar formed a true joint with a small osseocartilaginous protuberance projecting from the mid-verbetral border of the scapula. A pseudarthrosis was present in still another case. The omovertebral bar was short or incomplete in four patients, and its free cartilaginous extremity was anchored to the scapula by means of a fibrous band.

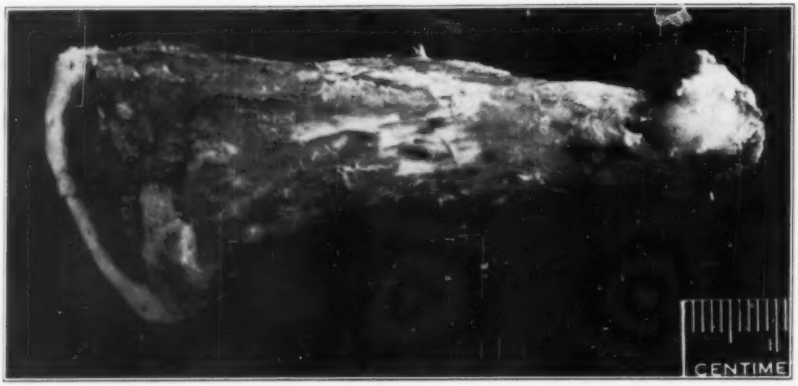

FIG. 4-A

FIG. 4-B

Two views of an omovertebral bone excised at operation. The distal end (left) was continuous with the vertebral border of the scapula; the proximal end (right) articulated with a cervical spinous process.

These operative findings failed to substantiate the hypothesis advanced by Willet and Wilsham in regard to the development of the omovertebral bone. They considered this condition to be an abnormal development of the epiphysis of the vertebral border of the scapula and consequently homologous to the suprascapular bone of some of the lower vertebrates. The hypothesis was based on a study of two specimens in which the omovertebral bone formed an uninterrupted chondro-osseous bridge between the scapula and the spine. Such a condition of a rigid pectoral girdle is known to exist normally in the thornback skate; it was present in three patients of this series. In the majority of patients, however, there was no indication that the omovertebral bone originates from the scapula.

OPERATIVE TREATMENT AND END-RESULT STUDY

One patient is included in this study upon whom surgery was performed at another hospital (Table II, therefore, includes only twenty patients). An omovertebral bone was reportedly excised from this patient at the age of six months; it was, however, still present fourteen months later when she was admitted to the clinic. Operation was advised on several occasions during the period of observation, but consent was not obtained. Sixteen years later, the deformity was essentially unchanged, and abduction of the shoulder remained markedly restricted.

Operation was undertaken in twenty patients (Table II) at the New York Orthopaedic Dispensary and Hospital. The age of these patients ranged from two to fifteen years. In

TABLE II
END RESULTS

	Case No.	Age at Operation	Period of Follow-up (*Years*)	Notes	Improvement in Position	Regeneration of Bone	Cosmetic Improvement	Improvement in Function
Group I 4 cases:	1	15	7		None	Marked	Poor	Poor
Scapula not transplanted to lower level	2	4	6		Good; "Spontaneous" correction	Minimal	Good	Excellent
	3	5	14		None	Minimal	Good	*
	4	3	13		None	Marked	Poor	Excellent
Group II 16 cases:	5	6	15	Rib anchorage released after operation because of brachial palsy	Complete recurrence	Moderate	Poor	Fair
Scapula transplanted to lower level	6	9	2½		Complete recurrence	Mild	Fair	*
	7	3½	7	Extensive subperiosteal release not performed	Excellent correction	None	Good	*
	8	7	6		Complete recurrence	Marked	Poor	*
	9	6	3		Complete recurrence	Minimal	Fair	*
	10	3½	3½	Osteotomy at base of acromion	Excellent correction	Minimal	Good	Excellent
	11	5	1½		Partial loss of correction	Moderate	Fair	Excellent
	12	3	8	Rib anchorage released after operation because of brachial palsy	Partial loss of correction	Marked	Fair	Fair
	13	6	14		Excellent correction	Mild	Good	Excellent
	14	2	17	Scapula not anchored to rib	Excellent correction	Moderate	Good	*
	15	8	1		Partial loss of correction	Mild	Good	*
	16	6	5½	Extensive subperiosteal release not performed	Complete recurrence	Marked	Poor	*
	17	4	14		Excellent correction	Mild	Good	Excellent
	18	11	6		Complete recurrence	Marked	Poor	*
	19	4	6		Partial loss of correction	Moderate	Good	Excellent
	20	7½	3½		Partial loss of correction	Marked	Poor	*

* Preoperative function was not appreciably impaired.

FIG. 5-A

FIG. 5-B

Fig. 5-A: Photograph of a patient with congenital elevation of the scapula.

Fig. 5-B: Same patient six years after excision of the omovertebral bone and resection of the superomedial portion of the scapula. Note degree of spontaneous correction of the high scapula.

four, no attempt was made to correct the abnormal position of the scapula; surgery was restricted, instead, to extensive subperiosteal stripping of the bone and resection of its superomedial portion which included the spine and supraspinous portion as well as a large part of the body of the scapula. An omovertebral bone was excised in three of these pa-

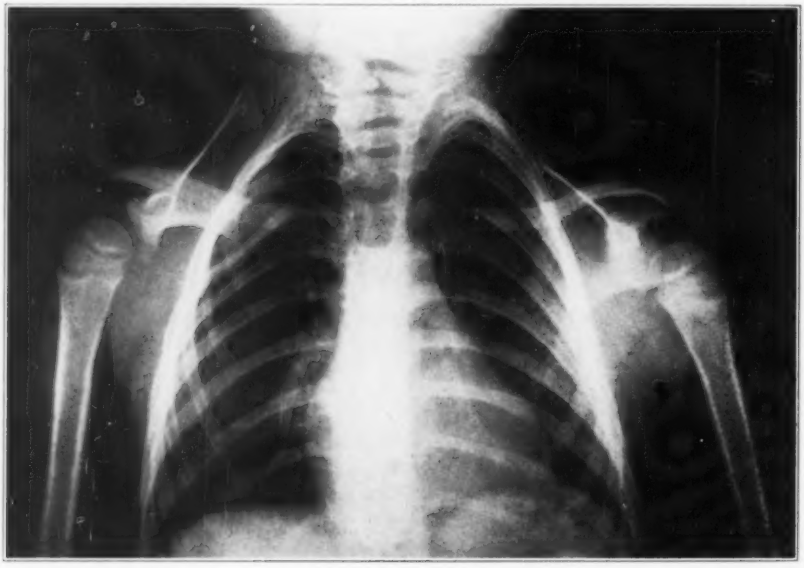

FIG. 6-A

Congenital elevation of the scapula before operation.

tients. Two patients were not appreciably improved in appearance because of the regeneration of bone at the site of the ostectomy. In the remaining two patients, the cosmetic

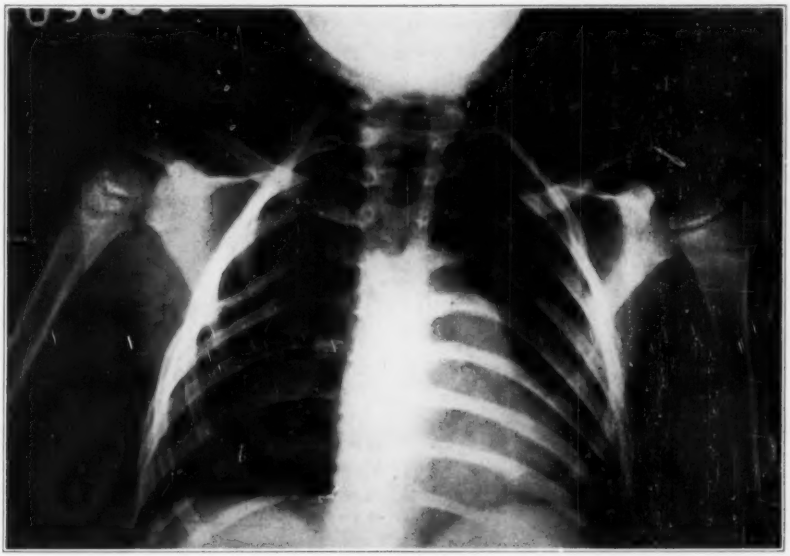

FIG. 6-B

Two weeks after operation by Schrock procedure. The wire suture anchoring the inferior angle of the scapula to a rib was removed because of paralysis of the brachial plexus.

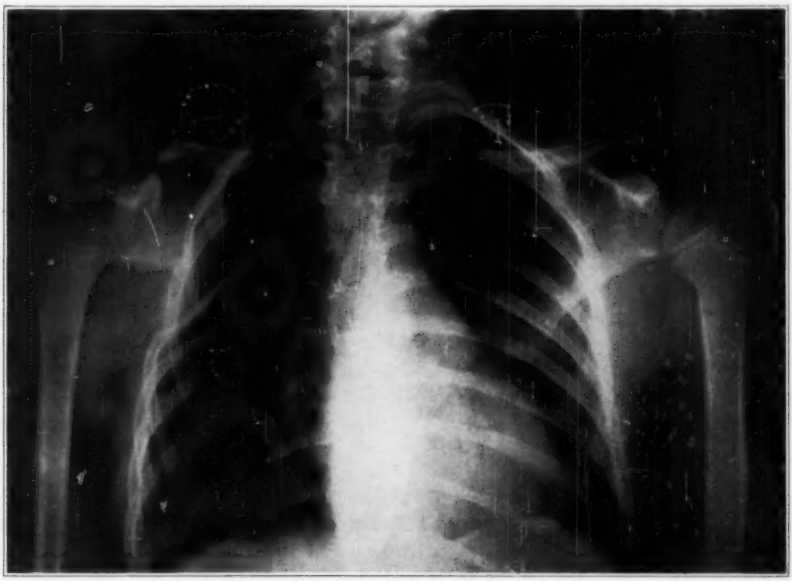

FIG. 6-C

Roentgenogram five years later. Note both the regeneration of bone at the site of the supraspinous ostectomy and the irregularity and diminished size of the scapula.

end result was good. Although no attempt was made to lower the scapula, gradual improvement in position took place spontaneously in one of these patients (Figs. 5-A and 5-B). Abduction was increased in two of the three patients in whom it had been restricted before operation.

In sixteen patients, the scapula was pulled down to a lower level following resection of its supraspinous portion. An omovertebral bone was present in six of these patients and it was excised. Extensive subperiosteal release of the scapula was done in fourteen, while in two patients the release was limited to the trapezius (upper and middle fibers), the levator scapulae, and the rhomboids. An osteotomy through the base of the acromion was considered necessary in only one patient who had a very severe deformity. The transplanted scapula was anchored to a rib in fifteen patients; in one it was sutured to the surrounding soft tissues only. In evaluating the end results in this group, the following were considered separately: improvement in the position of the scapula, improvement in appearance, and improvement in function. The period of follow-up examination ranged from one to seventeen years. Ten patients were followed for six years or longer.

I. *Improvement in Position*

Excellent correction of the undescended scapula was obtained in all of these patients at the time of operation; but follow-up examination revealed complete recurrence of the deformity in six. The patients' ages, variations in the operative procedure, and postoperative management were analyzed to determine their effect on the anatomical end result.

Age: Seven patients were from two to five years old when surgery was performed; correction of the high scapula was excellent in four of these (Figs. 1-A and 1-B). Some loss of the corrected position was noted in the other three patients. In a second group of nine patients, six to eleven years of age, there was full recurrence of the deformity in six and partial loss of correction in two. An excellent result was observed in only one patient. These findings seem to indicate that the best results are obtained when operation is performed before the age of five.

Internal immobilization of the scapula: In a two-year-old patient, the transplanted scapula was sutured to the surrounding soft tissues only; its inferior angle was not anchored to a rib. The deformity recurred in part and re-operation was strongly considered two and a half years after the operation. The patient left the clinic and she was not seen again until fifteen years later. At that time, the scapulae were level and the anatomical end result was excellent. Suturing the scapula to a rib did not appear to have been essential in this case. In two patients, three and six years of age, complete paralysis of the upper extremity developed after the operation. The sutures binding the scapula to a rib were consequently released to relieve the pressure on the brachial plexus. In spite of this release, a good degree of correction was maintained in the younger patient (Figs. 6-A, 6-B, and 6-C). The deformity recurred completely in the other.

Postoperative immobilization: This consisted of a sling and swathe, the strapping down of the shoulder with adhesive tape, or a strap harness over the shoulder buckled to a perineal strap. The period of postoperative splinting ranged from two to eight weeks. There was no correlation between the anatomical end result and the type or duration of external immobilization.

II. *Cosmetic Improvement*

The cosmetic end result was good in seven patients and only fair in four. Five patients were not improved by the operation. Cosmetic improvement was unquestionably good in all patients in whom the operative correction of the undescended scapula was well maintained. There was no constant correlation, however, between the anatomical and cosmetic result when the deformity recurred completely or in part. Much of the improvement in appearance gained by partial correction of the high scapula was often offset by regeneration of bone at the site of the supraspinous ostectomy. This new-bone

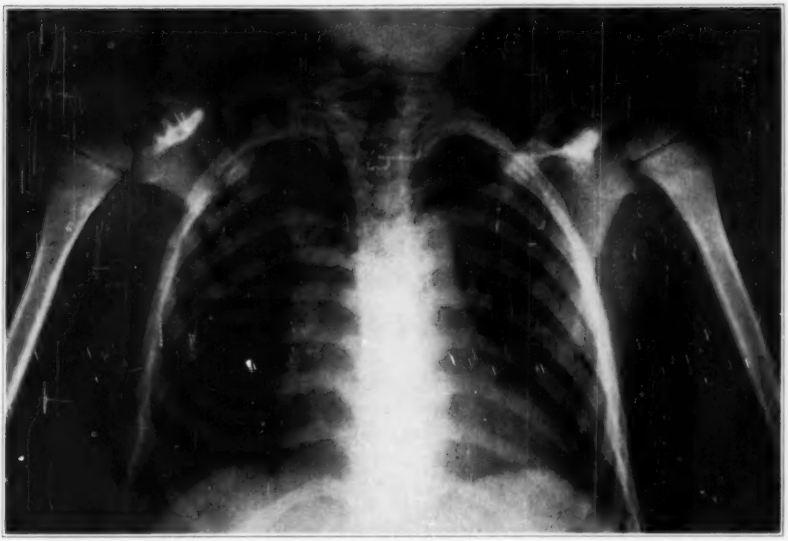

FIG. 7

Roentgenogram showing complete regeneration of the resected portion of the scapula.

formation was moderate to marked in nine of the sixteen patients (Figs. 6-A, 6-B, 6-C, and 7) and frequently caused an objectionable bulging at the base of the neck. On the other hand, re-elevation of the scapula, when not accompanied by regeneration of bone, resulted in satisfactory improvement in the upper line of the shoulder.

Other undesirable sequelae of the operation which affected the cosmetic end result were as follows: winging of the inferior angle of the scapula or flaring of the vertebral border of the scapula, or both (six patients), an unsightly, wide or keloid scar (seven patients), and a knoblike prominence of the sternoclavicular joint simulating a subluxation (two patients).

III. *Improvement in Function*

It is well known that motion in the shoulder is not always restricted in patients with congenital elevation of the scapula. Occasionally it is only slightly impaired, even though the deformity is associated with an omovertebral bone. Abduction was good to excellent in nine of the sixteen patients under discussion and the operation was undertaken solely for cosmetic improvement. In the remaining seven patients, abduction was greatly restricted. An excellent range of motion was obtained in five of these. Paralysis of the brachial plexus developed in two patients after the operation. Although the paralysis subsided after several months, some residual weakness persisted in the muscles of the shoulder girdle. The range of passive abduction was improved, but active elevation above 90 degrees was weaker than the normal and scapulohumeral rhythm was faulty.

DISCUSSION

In Sprengel's deformity, the scapula is elevated, adducted, and rotated downward by the trapezius (the upper and middle fibers), the levator scapulae, and the rhomboids. Release of the scapular insertions of these muscles is clearly indicated. Extensive subperiosteal stripping, as advocated by Schrock, seems unnecessary; there is no sound basis, clinical or anatomical, for continuing this practice. Moreover, release of the serratus anterior often results in some loss of power in the muscle with consequent "winging".

Paralysis of the upper extremity following transplantation of the scapula occurred in two patients in this series, an incidence of 12.5 per cent. Attempts at overcorrection should, therefore, be condemned. It must be emphasized, at this point, that the undescended scapula is frequently hypoplastic, especially in its vertical diameter. Lowering the scapula so that its inferior angle is level with that of the uninvolved side often amounts to overcorrection. It is interesting to note that in the two patients in whom brachial paralysis developed, follow-up roentgenograms revealed the scapula to be irregular and much diminished in size. Excessive traction plus extensive subperiosteal stripping may have destroyed the blood supply to the bone, resulting in aseptic necrosis. A similar complication has not been reported in the literature.

Regeneration of bone following subperiosteal resection of the supraspinous portion of the scapula was sufficiently marked to be of clinical significance in 58.7 per cent. Bone regeneration recurred in one patient after a second operation was performed to remove the first regenerated bone. Excision of the periosteum at the time of ostectomy may minimize this tendency to new-bone formation.

Spontaneous improvement of the deformity did not occur in any of the patients who had refused operation. Six of these were followed for periods ranging from four to sixteen years. On the other hand, in one of those operated upon, in whom no attempt was made to correct the high scapula, gradual improvement in position did take place over a number of years. The supraspinous and vertebral portions of the scapula were resected in this patient at four years of age. Since this was tantamount to lengthening the muscles responsible for maintaining the deformity, spontaneous correction was rendered possible with continued growth. This case serves to emphasize, further, the importance of early operative intervention. The best results in this series were obtained in patients in whom transplantation of the scapula was performed early, particularly before the age of five. It is the author's conviction that, in patients over six years of age, surgery should be restricted to extraperiosteal resection of the upper portion of the scapula and excision of the omovertebral bone when this structure is present.

An osteotomy of the base of the acromion or of the outer third of the clavicle is sometimes performed in the more resistant cases to facilitate pulling the scapula down to a lower level. Better results might have been obtained in these patients by excision of the outer end of the clavicle.

NOTE: The author wishes to thank Allen DeForest Smith, M.D., for permission to include in this study one of his private cases. He also expresses thanks to C. Z. Garber, M.D., for permission to reproduce his photographs of a resected omovertebral bone.

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RESECTION OF THE DISTAL END OF THE ULNA (DARRACH OPERATION)

An End-Result Study of Twenty-four Cases*

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Resection of the distal end of the ulna has been employed by many surgeons. However, infrequent mention of it is found in the literature. It was first described by Moore in 1880, and later by Van Lennep, Angus, Tillmanns, and Douglas.

In 1912, Darrach wrote the first of a series of articles advocating the use of the procedure, which resulted in its general acceptance. In recent years, there have been only a few papers, both recommending and criticizing the operation [10, 14]. There has been no analysis of end results.

The author's purpose in making this study was two-fold: first, to determine the efficacy of the procedure and, second, to seek in the variations in operative techniques the reasons for success or failure.

INDICATIONS FOR OPERATION

Darrach suggested as a general indication for the operation one which still obtains: any condition which causes derangement of the articular surfaces of the distal radio-ulnar joint, interfering with the action of the joint and resulting in either limitation of motion or pain on motion, or both.

Fracture of the radius which heals with overriding, angulation, or impaction, notably Colles' fracture, is the most frequent indication for the operation encountered in adults. In children, it is used to correct relative overgrowth of the ulna following injury to, and early fusion of, the distal radial epiphysis. Fracture of the head of the radius which has been treated by excision of the fragments may also result in relative shortening of the radius and subsequent wrist disability [12].

There are numerous other traumatic conditions, such as fracture of the head of the ulna and recurrent dislocation of the distal radio-ulnar joint, which may necessitate correction. Excision of the head of the ulna has also been reported by Freese as a treatment for fresh Colles' fractures which are severely comminuted. There are likewise non-traumatic conditions for which the operation has been employed: cyst of the head of the ulna, rheumatoid arthritis, and obstetrical palsy. The procedure may also be used in conjunction with wrist fusion in an attempt to improve rotation of the forearm.

OPERATIVE PROCEDURE

In the operative procedure described by Darrach first in 1912 and later in more detail in 1936, he advocated the use of an incision which extended proximally from the ulnar styloid process. The bone was approached by separating the extensor carpi ulnaris and flexor carpi ulnaris, avoiding the dorsal cutaneous branch of the ulnar nerve. The periosteum was incised and reflected from the distal end of the ulna. About three centimeters of the distal portion of the ulna was removed by an oblique osteotomy. The distal fragment was then dissected free subperiosteally, and the ulnar styloid process was osteotomized at its base, but left *in situ*.

The periosteal sleeve was left to provide a firm attachment for the styloid process and its ulnar collateral ligament for the purpose of preventing abduction laxity. The

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TABLE I

DIAGNOSES IN TWENTY-FOUR CASES OF RESECTION OF THE DISTAL END OF THE ULNA

Diagnosis	Patients Treated (*Number*)
Malunion of Colles' fracture	11
Non-union of Colles' fracture	1
Comminuted Colles' fracture (fresh)	1
Growth disturbance of the distal end of the radius secondary to trauma	3
Madelung's deformity	1
Deformity of the wrist following excision of the head of the radius	1
Non-union of fracture of the ulnar styloid process with superimposed wrist strain	1
Old fracture of the head of the ulna with radio-ulnar synosteosis	1
Recurrent dislocation of the distal radio-ulnar joint	1
Foreign body (wood splinter) in wrist	1
Cystic disease of the head of the ulna	1
Cystic tenosynovitis of extensor tendons and degenerative arthritis, distal portion of the ulna	1
Total	24

wound was closed in layers. No splint was used and active motion was encouraged in twenty-four hours.

In the hands of some surgeons, the original procedure has been modified. Instead of cutting the distal end of the ulna obliquely, Cotton and Morrison made a conical stump. Others advocate the subperiosteal resection of the styloid process; some feel that the entire excision should be done extraperiosteally in order to prevent regeneration of the ulna, which might cause arthritis by contact between the distal portion of the radius and the ulna. McLaughlin, in an attempt to prevent this complication, but retaining Darrach's principles, does his resection subperiosteally, making a point of invaginating the periosteal sleeve with sutures to form a narrow cord. Thus, he feels he has retained the advantage of a periosteal strut, but has minimized the opportunity for the ulna to regenerate.

ANALYSIS OF CASES

Twenty-four cases of resection of the distal portion of the ulna were studied. Twenty-one additional patients were reviewed but were not included in this series for several reasons: either the follow-up was too brief or too inadequate, or there was an additional pathological condition which complicated the picture and made a fair end-result evaluation difficult. Such conditions as nerve and tendon injuries, rheumatoid arthritis, and obstetrical paralysis come within this group.

TABLE II

OPERATIVE PROCEDURES PERFORMED IN CONJUNCTION WITH EXCISION OF THE HEAD OF THE ULNA

Operation	Cases (*Number*)
Wedge osteotomy of the distal portion of the radius (to restore normal angulation of the radial articular surface)	4
Open reduction of non-union of a Colles' fracture	1
Closed reduction, fresh Colles' fracture	1
Excision of distal radio-ulnar synosteosis	1
Excision of the head of the radius (when excision of the head of the ulna did not adequately improve rotation)	1

TABLE III

CRITERIA FOR GRADING END RESULTS

1. Satisfactory results	
	Excellent: a strong, symptom-free wrist, cosmetically pleasing and with full function.
	Good: rare, minimal symptoms; function relatively unimpaired.
	Fair: rare, minimal symptoms; slight impairment of function.
2. Unsatisfactory results	
	Poor: bothersome symptoms or significant impairment of function.

Of the twenty-four cases studied, eleven of the patients were men and thirteen were women. Their ages at the time of operation ranged from six to seventy-two years, and averaged thirty-eight years. Their occupations varied widely; there were several students, a dentist, a concert pianist, a longshoreman, and a window-cleaner, but housewives were the most numerous, comprising over half the group. The follow-up period varied from one to thirteen and one-half years, and averaged four and one-half years.

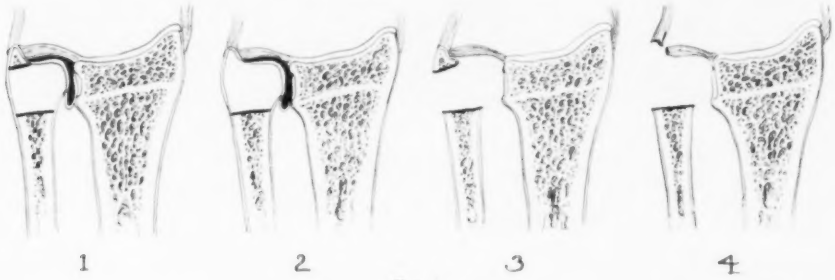

FIG. 1

Drawings illustrate variations in the operative technique in twenty-four cases of excision of the head of the ulna (each group consists of six cases).
Group 1. Subperiosteal resection—ulnar styloid process not excised.
Group 2. Subperiosteal resection—ulnar styloid process excised.
Group 3. Extraperiosteal resection—ulnar styloid process not excised.
Group 4. Extraperiosteal resection—ulnar styloid process excised.

Diagnoses

The presenting diagnoses were many and varied. Complications of Colles' fractures made up over half the number of cases in this series. Growth disturbance of the distal portion of the radius in children was the next most frequent indication for operation. The remainder of the group includes some relatively unusual diagnoses (Table I).

History and Examination

Almost all of the patients presented the same complex of signs and symptoms: (1) pain (especially at extremes of pronation and supination), (2) limitation of motion (especially pronation and supination), (3) weakness of the wrist and of grip, and (4) deformity (either radial deviation of the hand or an unsightly dorsal, or occasionally volar, prominence of the distal portion of the ulna). With few exceptions the disability was severe. The duration of disabling symptoms as a rule was less than a year, although a few patients had been incapacitated from five to ten years.

Variations in Operative Procedure

The basic variations in the operative techniques used in this series of cases are illustrated in Figure 1. Osteotomy of the ulna was done both transversely and obliquely. Additional operative procedures were performed in conjunction with excision of the head of the ulna in eight cases (Table II).

FIG. 2

FIG. 3

Fig. 2: Typical roentgenographic appearance of a wrist after extraperiosteal resection. No regeneration of bone was noted, two and one-half years postoperatively.

Fig. 3: Complete regeneration of the head of the ulna following subperiosteal resection twelve and one-half years earlier; the ulnar styloid process was not excised. The patient was fourteen years of age at the time of operation.

Postoperative Treatment

The usual postoperative treatment consisted of immobilization with an elastic bandage or with a forearm splint for periods ranging from twenty-four hours to twelve days. Several cases were immobilized for a longer period of time,—one for as much as five weeks. In the four cases in which wedge osteotomy was done, immobilization varied from three to twelve weeks. Following the immobilization period, active use was encouraged, and all patients received occupational and physical therapy.

Results

In grading end results, the factors taken into consideration were: pain, weakness or fatigue, deformity (the cosmetic result), and function.

The criteria employed are presented in Table III. There were six excellent, eleven good, and four fair results. Three were unsatisfactory. However, all the patients, including those with unsatisfactory results, were pleased with their condition and felt that they had been helped.

A history of postoperative pain was obtained from nine of the twenty-four patients. In no case was it a serious symptom. Five had mild aching in damp weather; the remaining four had pain following marked fatigue or overexertion of the wrist, but they minimized its importance.

Eleven patients had no detectable weakness. Two noted torsion weakness,—one while using a screw driver, the other while wringing clothes. The remaining eleven, housewives for the most part, had a tendency, on lifting over-heavy saucepans from the stove, to favor the affected wrist.

All of the patients were pleased with their cosmetic results, and were delighted to be rid of the unsightly prominence of the head of the ulna. No patients had any permanent radial deviation of the wrist. Two wrists showed 20 degrees of ulnar deviation associated

FIG. 4

FIG. 5

Fig. 4: Retrograde regeneration of bone from the ulnar styloid process seven years after subperiosteal resection of the head of the ulna.

Fig. 5: A case of subperiosteal resection five and one-half years postoperatively showing spike-like regeneration of the ulna. The ulnar styloid process remains ununited.

with deformity of the distal end of the radius; several had a slight decrease in coronal diameter.

Although only four patients had a complete range of motion, few were conscious of any limitation; all were improved over their preoperative status. The motion most missed was a lack of 10 to 20 degrees of supination. Because of this slight limitation, three patients complained of an inability to hold small change in the open palm without dropping it. Two others were unable to crumb a table into the affected hand for the same reason. Residual dorsal tilt of the radius accounted for a loss of 10 to 40 degrees of palmar flexion. Extension and pronation were seldom affected.

Patients with simple excision of the head of the ulna had, on the average, a period of partial disability of two and one-half months. As a rule, they returned to light or medium work in one month. When the entire group is analyzed, including those patients who had additional operative procedures performed, the average period of partial disability was five months.

All patients, even those in whom the results were classified as unsatisfactory, returned to their preoperative employment or to other work which was no less strenuous. This included a longshoreman who received a 45 per cent. disability rating from the Workman's Compensation Board. When last heard from, he was still working at the same heavy job.

REGENERATION OF THE DISTAL PORTION OF THE ULNA

No regeneration of bone was noted in the twelve cases of extraperiosteal resection (Fig. 2). Of the twelve subperiosteal excisions of the head of the ulna, nine showed definite evidence of some bone regeneration. Two children demonstrated a remarkable degree of bone regeneration with re-formation of a distal radio-ulnar joint (Fig. 3). A similar picture, although less pronounced, was seen in the roentgenograms of two adults (Figs. 4 and 5).

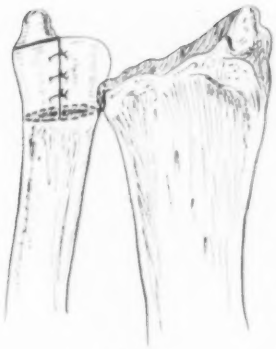

FIG. 6

Suggested level for ulnar osteotomy. The stump lies adjacent to the sigmoid notch of the radius. The resection has been done subperiosteally and the ulnar styloid process has been left *in situ*.

SUMMARY OF UNSATISFACTORY RESULTS

CASE 1. J. O'C., a six-year-old boy, presented a Madelung-type growth deformity, secondary to a fracture of the distal portion of the radius. The ulna protruded one inch distal to the radius; this associated with 40 degrees of fixed radial deviation. The distal portion of the ulna was resected; the deformity of the radius was corrected by wedge osteotomy. Nine years later, there was recurrence of the deformity, with an anterior angulation of the distal radial articular surface of 90 degrees and overgrowth of one-half inch of the ulna. Subsequent osteotomy and wrist fusion gave a good result. This illustrates the problems encountered in the correction of growth deformities in children.

CASE 2. S. L., a truck driver, thirty-nine years old, had a distal radio-ulnar synosteosis following fracture of the head of the ulna. The wrist was fixed in 60 degrees of supination, but was symptom-free. Eighteen months postoperatively, the synosteosis had redeveloped, this time in 10 degrees of supination. No explanation for the recurrence was found in the review of this case.

CASE 3. A. A., a seventeen-year-old boy, had a malunion of a Colles' fracture with marked limitation of all wrist motions and a decrease in wrist strength of 50 per cent. At operation, because rotation had not been adequately improved by resection of the head of the ulna, the head of the radius was also excised, allowing full pronation and supination. A distal radio-ulnar synosteosis developed postoperatively, fixing his wrist in a neutral position. Flexion-extension was greatly improved, however, and he had normal strength. His record revealed that he had not reported to the Clinic for the first ten weeks after operation. It is tempting to blame this poor result on a lack of postoperative supervision.

DISCUSSION

Although this is too small a series of cases from which to draw statistically significant conclusions, the author has received several definite impressions from his analysis which are of interest:

1. Resection of the head of the ulna is an excellent procedure for the rehabilitation of patients with severe disability at the distal radio-ulnar articulation;

2. The variations in operative techniques were of no significance in determining the success or the failure of the procedure; the distal portion of the ulna can be resected subperiosteally or extraperiosteally; the styloid process can be excised or left *in situ;* and the osteotomy can be done obliquely or transversely—all with the expectation of a satisfactory result.

Since the duration of postoperative immobilization varied widely, it was suspected that it might be an important factor, influencing end results. This did not prove to be so. It was noted, however, that the length of immobilization did influence the postoperative disability period in cases of simple resection of the head of the ulna, for the briefer the period of immobilization, the sooner the patient returned to full work.

There does appear to be one important factor in the determination of the quality of end results,—*the amount of bone resected*. At follow-up roentgenographic examination, it was noted that almost all of the patients with good or excellent results had had either very little bone removed or the process of regeneration had been very active with little final discrepancy between the lengths of the radius and ulna. As was mentioned earlier, several demonstrated an apparently functional distal radio-ulnar joint postoperatively. Inasmuch as the strength and the stability of such wrists were unimpaired, one is led to believe that physiological regeneration is an asset rather than a detriment to the end result. In further support of this thesis, it is interesting to note that two of the four patients with fair results had over one inch of discrepancy between the lengths of the radius and ulna at follow-up examination.

Instability and Weakness

Some writers feel that detachment of the ulnar collateral ligament unavoidably results in a weak wrist [14]. With this hypothesis in mind, Darrach purposely left a continuity of structures by doing a subperiosteal resection. Inasmuch as there was no relationship between postoperative weakness and the variations in operative techniques, and since extraperiosteal resection compared favorably with subperiosteal resection, this group of patients suggests that compromising the ulnar collateral ligament does not affect functional end results.

Radial Deviation Secondary to Extraperiosteal Resection

Many surgeons have avoided extraperiosteal resection because of the fear of radial deviation of the hand if the ulnar collateral ligament is cut. This did not occur in any of the twelve cases of extraperiosteal resection in this series.

Arthritis of the Distal Radio-Ulnar Joint

Extraperiosteal resection has been favored by some surgeons since it prevents regeneration of bone and the possibility of the development of subsequent arthritis of the distal radio-ulnar joint. Of the nine patients with varying degrees of regeneration associated with subperiosteal resection, only one complained of an occasional mild ache (when she squeezed oranges). Six of the entire group of twenty-four patients described a grinding or clicking sensation in the wrist on forced rotation. This symptom was not a bothersome one and could not be correlated with regeneration of the ulna, as it occurred just as frequently in the patients with extraperiosteal resection.

CONCLUSIONS

From a review of this series of cases, it is evident that the best results were obtained in those patients who had had a minimal amount of bone removed or in those in whom the process of bone regeneration was especially active.

It might therefore be suggested (Fig. 6):

1. That emphasis be placed, not on the amount of ulna to be resected, but rather on the amount of ulna to be preserved. (Only that amount of bone should be removed which would allow the distal portion of the ulna to lie adjacent to the sigmoid notch of the radius. Preoperative roentgenograms should be studied to determine the proper amount);

2. That excision of the distal portion of the ulna should be done subperiosteally to encourage anatomical and physiological regeneration of the distal end of the ulna;

3. That the ulnar styloid process, with the ulnar collateral ligament attached, be left *in situ*.

The purpose of these measures would be to effect, as much as possible, the restoration of the normal anatomy of the distal radio-ulnar articulation.

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TENDON TRANSPLANTATIONS IN THE LOWER EXTREMITY

A Review of End Results in Poliomyelitis *

I. Tendon Transplantations about the Foot and Ankle

BY JOHN A. REIDY, M.D., THOMAS F. BRODERICK, JR., M.D., AND JOSEPH S. BARR, M.D., BOSTON, MASSACHUSETTS

In the centuries antedating the era of modern surgery, paralytic foot deformities were treated by splints, braces, manipulation, and exercises. Operative procedures such as bone stabilization and tendon transplantations are of relatively recent origin. The first tendon transfer of any type (transplantation of peroneus longus and brevis into the tendo achillis) was performed by Nicoladoni in 1881. Since that original report a voluminous literature has appeared on the subject of tendon transplantation. A great variety of operative techniques have been described, but there have been very few reports of the long-term end results of these operations.

In an attempt to determine which of the available tendon transplantations is most beneficial in a given case of weakness or deformity about the foot and ankle, we have reviewed 100 such cases of patients treated in the Poliomyelitis Clinic at the Massachusetts General Hospital. Of this number, sixty were males and forty were females. These patients were subjected to 125 transplantations, which were carried out on 110 extremities. The operations were performed over a thirty-year period, from 1920 through 1949. The interval between operation and end-result evaluation ranged from one to twenty-eight years, with an average of seven years. This long period gives us an excellent opportunity to evaluate the very late end results.

The age of the patients at the time of operation varied from five to forty-six years. Twenty-three patients were less than eleven years old, forty-six were eleven to fifteen years of age, and fifty-six were sixteen years of age or older.

* This study was aided by a research grant from the National Foundation for Infantile Paralysis, Inc., and was carried out at the Massachusetts General Hospital.

TABLE I

TENDON TRANSPLANTS ABOUT THE FOOT AND ANKLE

	Anterior	Posterior	Total
A. Peroneals	54	14	68
Peroneals retransplanted	2	1	3
B. Peroneals with another tendon	5	10	15
C. Anterior tibial	7	1	8
Anterior tibial retransplanted	1	0	1
D. Posterior tibial	4	4	8
Posterior tibial with another tendon (other than peroneals)	0	1	1
E. Toe extensors to metatarsals	17	0	17
F. Toe flexors (alone or with extensor hallucis longus)	0	3	3
G. One third tendo achillis	1	0	1
TOTAL	91	34	125

TABLE II

OPERATIVE PROCEDURES SUPPLEMENTING TENDON TRANSPLANTATION

Triple arthrodesis		104
at time of transplant	93	
before transplant	7	
after transplant	4	
Interphalangeal fusion of great toe		4
Soft-tissue procedures		13
No other surgery		4
TOTAL		125

Tendon transplantations in the region of the foot may be grouped into three main categories:

1. *Anterior type.* In this group the new insertion of the transplanted tendon is in the dorsum of the foot distal to the ankle joint to re-establish or to strengthen the function of dorsiflexion (74 cases).

2. *Posterior type.* In this, the tendon is attached posterior and distal to the ankle joint, in the os calcis or tendo achillis to improve the power of plantar flexion, establish more effective "take-off", and diminish the calcaneus type of gait (34 cases).

3. *Toe-extensor transplant.* In this operation the extensor tendons of the toes are transferred to the dorsum of the foot to assist in dorsiflexion and to eliminate "cock-up" deformities of the toes (17 cases).

It is readily seen from Table I that in this series of cases the peroneal tendons were transplanted much more frequently than any others in the foot. In paralytic involvement of the lower extremity, the peroneal muscles frequently retain useful power. When the foot is being stabilized by arthrodesis, these tendons are usually exposed and frequently are severed to allow more adequate exposure. Thus it is relatively easy to transplant the peronei to reinforce weakened anterior or posterior muscle groups. By far the majority of the tendons were transplanted anteriorly for the correction of foot-drop.

Most of the patients in this series had bone deformity or instability of such degree that arthrodesis of the foot, or some other bone procedure, was done in addition to the tendon transplantation. Other procedures carried out at the time of transplantation included such measures as interphalangeal joint fusion, lengthening of the tendo achillis, or plantar fasciotomy.

Table II lists the other procedures which were carried out. The types of preoperative deformity of the foot and the tendons which were transplanted are shown in Table III.

TYPES OF FOOT DEFORMITY

As might be expected, all types of foot deformity were encountered in this series. Talipes equinus, calcaneus, valgus, varus, and cavus occurred as single deformities and in various combinations.

The causative factors responsible for the production of these deformities include:

1. Imbalance between opposing muscle groups of the calf or of the intrinsic muscles of the foot;
2. The pull of gravity on a foot with weakened musculature;
3. Lack of proper splinting or adequate physical therapy during the acute phase of the illness;
4. Age at onset.

The patient who is an adult when poliomyelitis develops rarely has severe deformity of the foot such as is seen in patients in whom the onset is in childhood. Normally functioning muscles must be present throughout the growing period if the bones of the foot are to have normal adult size and form. The most severe foot deformities are seen in patients in whom poliomyelitis occurred at an early age and with severe muscle imbalance.

OPERATIVE END-RESULTS

As the tendon transplantations in this series of cases were done primarily to improve power in dorsiflexion or plantar flexion, the end-result rating was based on the effective functional result.

In the first group were the *good* and *excellent* results,—that is, those patients who had an excellent functioning transplant with good to normal power. The second group consisted of those rated *fair*,—that is, there was some effective power in the transplant but not sufficient to rate it *good*. In the third group were those in whom the transplant functioned poorly or not at all.

In Category 1 (anterior transplants to improve dorsiflexion) the results were classified as follows:

	No. of Transplants	*Per cent.*
Good to excellent	23	32.4
Fair	30	42.3
Poor to zero	18	25.3
	71 *	100.00

In Category 2 (posterior transplants to improve plantar flexion) the results were classified as follows:

	No. of Transplants	*Per cent.*
Good to excellent	9	26.5
Fair	10	29.4
Poor to zero	15	44.1
	34	100.00

Category 3 comprises a small group of cases, seventeen in all, in which the long-toe extensors were used to improve dorsiflexion and cavus of the foot and to relieve "cock-up" toe deformities. Of the seventeen cases, the deformity in eleven was improved by the operation, in five it was essentially the same, and in one a new deformity developed.

* In three cases, transplants over-pulled into new deformities and had to be retransplanted. End results were recorded only after the second operation.

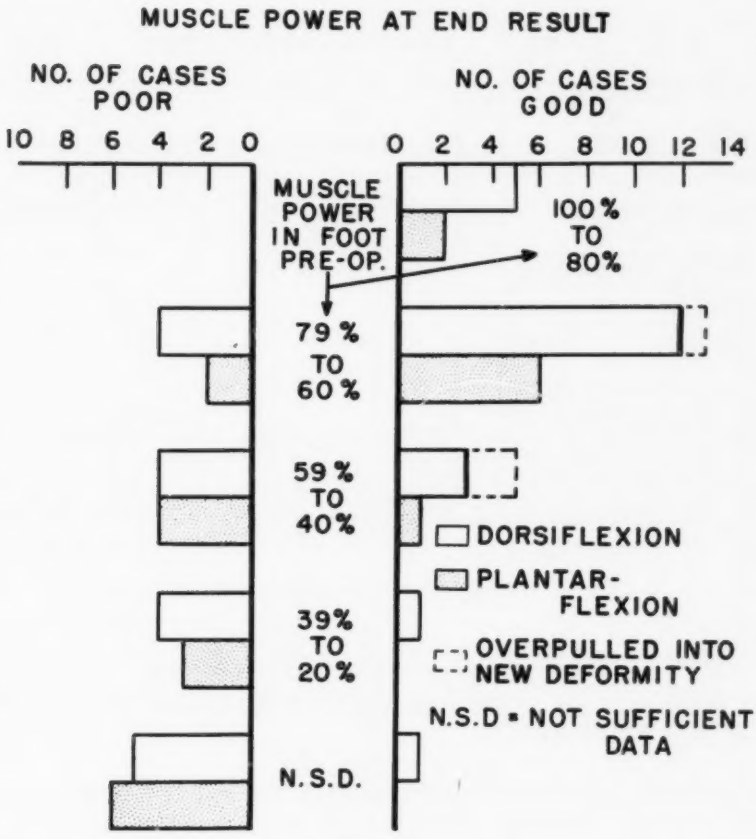

CHART I

Relation between preoperative muscle power in foot and postoperative power of dorsiflexion or plantar flexion.

The improvement noted in these cases seemed less related to transference of muscle power than to the release of contractures and the bone fixation which was done in ten of the seventeen patients, six having interphalangeal fusions and four triple arthrodeses.

Although it was impossible to analyze statistically the functional results in this category, the best results, both in correction of deformity and in function of the transplant, seemed to be obtained when the extensor hallucis longus was transplanted either with or without the common extensors. The poorest results occurred when only the common-toe extensors were transplanted.

OPERATIVE TECHNIQUE AND AFTER-CARE

We had hoped to be able to study the effect of variations in operative technique and in after-care on the eventual results. Unfortunately this was not possible, as there were too many individual variations in technique and too few cases in each class. These cases represent a thirty-year evolutionary change in the operative treatment of feet affected by poliomyelitis, and the operations were performed by at least a score of surgeons, in-

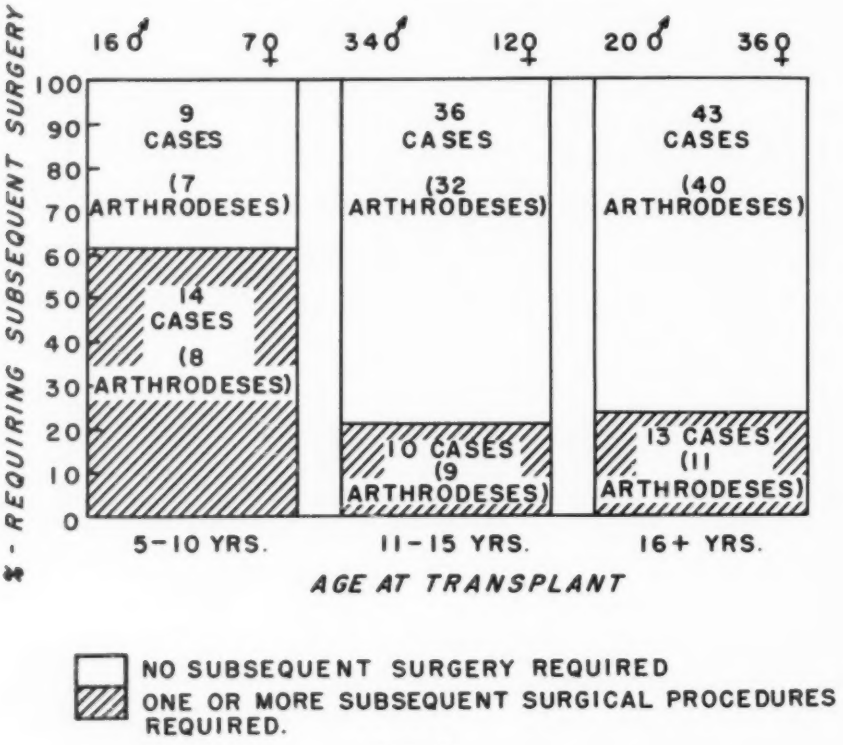

CHART II

Relation between age at transplant and necessity for subsequent surgical procedures (based on 125 transplants).

cluding residents. Obviously, by the standards of 1952, the unsatisfactory results in a number of our patients operated upon in the 1920 to 1930 era might be attributed to poor operative technique or to improper after-care. In general, the patients were operated upon by one-stage procedures, the tendon transplantation being done at the same time as the stabilization. The commonly accepted techniques described by Mayer, Ober, Steindler, Hoke, and others were used. These techniques have been adequately described and illustrated [2] and need not be discussed here.

Success in tendon transplantation in the foot, as elsewhere, depends upon the fulfillment of certain requirements which have been previously set forth by one of us:[1]

"1. There must be a free range of passive motion and no deformity in the joint or joints to be activated by the transplanted muscle.

"2. The muscle or muscles to be transposed must have sufficient power to substitute adequately for the paralyzed muscle or to satisfactorily reinforce a weakened one.

"3. The line of pull of the transposed muscle must be direct and should follow the course of the muscle to be replaced.

"4. Its anchorage should be into bone, through drill holes or subperiosteally if possible. Tendon to tendon gives less secure fixation.

"5. The normal blood and nerve supply of the muscle must be carefully preserved.

"6. Muscles which have similar or related actions give better results than antagonists.

"7. The amplitude of pull of the transposed tendon must be of the same order as that of the paralyzed one for which it substitutes.

"8. The gliding mechanism of the transposed tendon must be preserved by gentle handling and by placing it in a muscular or subfascial compartment and not subcutaneously.

"9. The tendon should be attached under the proper amount of tension. Too much laxity or too much tension will jeopardize the result. As a general rule, the joint should be brought into the position in which the muscle origin and its new insertion are approximated and the tendon attachment made under slight to moderate tension.

"10. The joint should be splinted in this position postoperatively and no strain should be allowed on the tendon until firm healing has occurred—three weeks is usually regarded as sufficient time.

"11. Careful functional re-education of the transposed muscle is essential, and it must be protected from undue fatigue and strain until maximal function has been obtained."

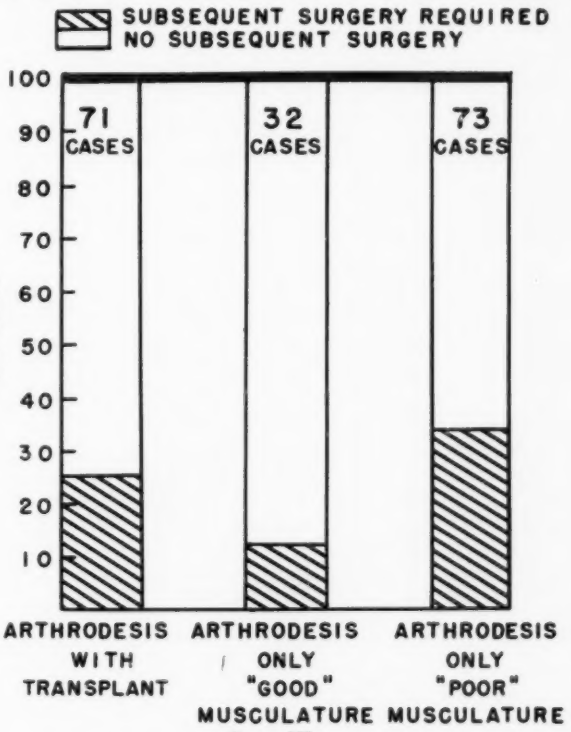

CHART III

Arthrodesis of foot with and without tendon transplantation and proportion of each group requiring subsequent surgery.

There were complications in 9 per cent. of this series of 125 operations; they included two hematomata, two areas of slough or pressure necrosis, three major and two minor septic processes in the wounds. Most of the complications were in the earlier cases, before the era of chemotherapy and antibiotics. The complications were ultimately controlled, and there were no deaths.

The relationship between the preoperative muscle power in the foot and the postoperative power in dorsal and plantar flexion is shown in Chart I. It can be seen that, if the musculature of the foot is strong preoperatively, the chances of good function postoperatively are much greater than when the muscle power is poor.

Those attaining *good* to *excellent* power postoperatively were compared with the *poor* to *zero* group in respect to age at the time of surgery. It was found that approximately 70 per cent. of those operated upon under eleven years of age had poor power in their transplants, while those in the older age groups fared somewhat better. Of the children eleven to fifteen years old, 40 per cent. had *poor* results, as compared with 55 per cent. for the adult group.

In the older age groups, the anterior transplants were definitely more satisfactory

TABLE III

PREOPERATIVE DEFORMITY AND TENDONS TRANSPLANTED

Type of Deformity	Tendons Used							Total Deformities
	Peroneals (one or both)	Anterior Tibial	Posterior Tibial	Toe Extensors	Toe Flexors	One Third of Tendo Achillis	Combinations	
Valgus	38			3	1		7	49
Varus	9	8	8	3		1	2	31
Cavus	4			2			2	8
Equinus	16			3			1	20
Calcaneus							5	5
Toe deformities only				6	1			7
Not sufficient data	1							1
Retransplants	3	1						4
Total tendons transplanted	71	9	8	17	2	1	17	125

than the posterior. Of the children eleven to fifteen years old, 65 per cent. had *good* to *excellent* dorsiflexion postoperatively, as did 58 per cent. of the group sixteen years old and over. In the younger children, however, anterior and posterior transplants had an equally high number of unsatisfactory results.

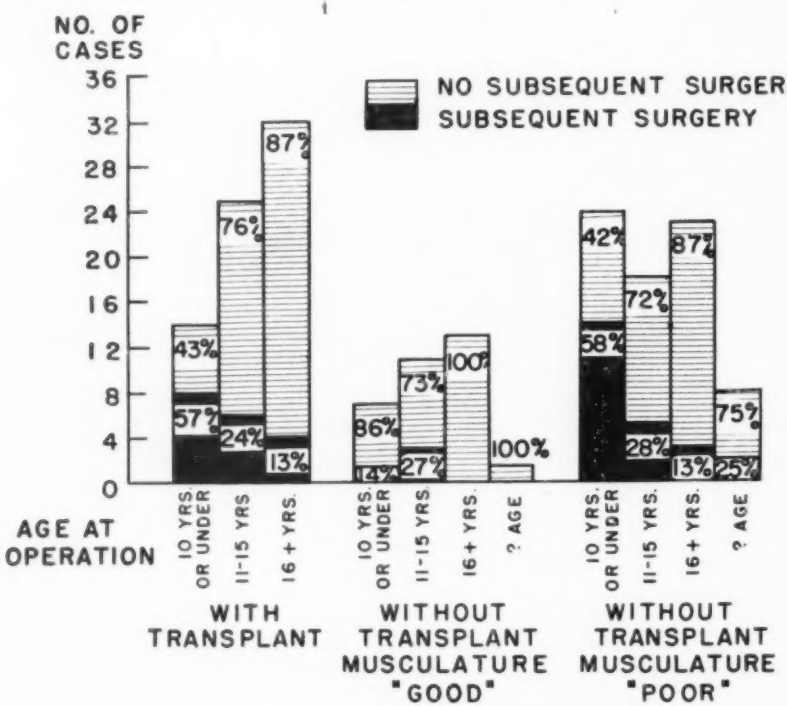

CHART IV

Relationship between age at operation and subsequent surgical procedures in the transplant and two control groups.

Many children operated upon before the age of eleven were found at end result to have had a recurrence of their old deformity or to have had a new one develop because of continued muscle imbalance. Most of these children required one or more subsequent operative procedures on their feet,—that is, 61 per cent. of the twenty-three children aged ten years or less at the time of the first transplant were subjected to further surgery, while less than 25 per cent. of the other two groups needed similar procedures (Chart II). The distribution of males and females in each group, as well as the number of arthrodeses performed at the time of transplantation, is recorded. There appears to be a marked decrease in the need for subsequent surgery if the first operative procedure can be postponed until after the age of twelve.

In studying these transplantations, it was evident that the accompanying stabilization of the foot, performed in the majority of the cases, played a most important part in the correction of the preoperative deformity and instability of the foot. In an attempt to determine how much the tendon transplantation itself contributed to the functional result, a group of 105 controls who had had arthrodesis of the foot without tendon transplantation were collected and studied. The incidence of subsequent surgical procedures following arthrodesis alone was compared with their incidence following tendon transplantation and arthrodesis.

The muscle examinations of these control cases indicated that, in a large number, the musculature about the foot and ankle was so poor that no tendon was available for transplantation. Therefore, the controls were divided into two groups, those with *good* and those with *poor* musculature below the knee. These two groups were compared with seventy-one of the group who had had transplantation as well as arthrodesis (Chart III). (The remaining fifty-four of the 125 transplantations were so complicated by numerous operative procedures that they were considered unsatisfactory for comparison.)

These figures show that patients with *good* muscle power and an arthrodesis alone were less likely to require a second operation than were those who had had a transplantation plus the arthrodesis. The preoperative muscle power of the transplantation group was comparable to the *good* control group. If the tendon transplantation effectively prevented or decreased the tendency to recurrent deformity, one would expect that the incidence of further surgery would be lower than that of the *good* control group. This, however, was not true.

The age at operation was reviewed in all three groups. The transplantation and *good* control groups as a whole were comparable in respect to the proportion of cases in each age group. The *poor* control group had a substantially larger proportion of children operated upon under eleven years of age. Over half of this latter group required more surgery (fourteen out of twenty-four patients were operated upon a second time).

Chart IV gives the figures for each age group in both the transplantation and control groups.

DISCUSSION

This review of muscle transplantations about the foot and ankle shows that the transplantations are not uniformly successful. In fact, there was failure of the transplant to function satisfactorily in about one third of the cases, and the result could be classified as *good* or *excellent* in slightly less than one third of the cases.

The percentage of failures was considerably higher for posterior transplants than for anterior ones.

If the transplant was used to reinforce a weak but not completely paralyzed muscle, the result was often good. In some instances the combined function seemed to be synergistic and of greater power than one would anticipate. However, in several cases a *good* to normal muscle was transplanted and the resulting function was *poor* to *zero*.

Although the results of transplantation in the younger age groups were disappoint-

ing on the whole, in some patients, operated upon during the growing period, transplantation alone was used to correct or prevent increasing deformity with gratifying results. It is important to analyze carefully the situation before transplantation is done, as functional balance can be disturbed to a considerable degree in a mobile foot. For instance, a brace-free foot which is stable in a valgus position due to function of the peroneals may, by a transplant to improve dorsiflexion or plantar flexion, be rendered so unstable in the lateral plane that the support of a brace may be necessary until the foot has grown sufficiently to allow stabilization by arthrodesis.

SUMMARY AND CONCLUSIONS

1. The long-term end results of tendon transplantations about the foot and ankle in 100 poliomyelitic patients have been studied.

2. In all but a few instances, the transplantation was an adjunct to bone stabilization of the foot.

3. The peroneal tendons were most frequently transplanted.

4. Transplantations to reinforce power in dorsiflexion were done more frequently and in general were more successful than were the posterior transplantations which were done to improve plantar flexion.

5. Approximately one third of the transplantations were rated as *failures*, one third as *fair*, and one third as *good* to *excellent*.

6. The presence of good muscle power before operation favorably influenced the end result.

7. Operations done before the age of eleven were likely to be unsuccessful, and re-operation was necessary in 60 per cent. of these cases.

8. It would appear from our studies that, in the presence of good muscle power about the foot and ankle, triple arthrodesis without tendon transplant produces an excellent functional result. This is especially true if the deformity or instability can be treated conservatively until the patient is at least thirteen years old.

9. There is some evidence that arthrodesis of the interphalangeal joints of the toes may be sufficient to correct the deformity of "cock-up" toes and to permit the toe extensors to dorsiflex the foot without transplanting the tendons to the metatarsal necks.

10. In general, the combined operation of arthrodesis and tendon transplantation should be reserved for feet with marked muscle imbalance. In properly selected cases, tendon transplantation improves the result of arthrodesis by reinforcing power in dorsiflexion or plantar flexion and may prevent recurrence of deformity caused by unbalanced muscle pull.

11. In this study we have learned that no two cases of poliomyelitis are identical; that restoration of a weakened foot to normal strength and function is impossible. Nevertheless, tendon transplantation, when combined with stabilization procedures, may markedly improve function of the foot.

NOTE: The assistance of Miss Anne Dunmore in collecting and analyzing the statistical information is gratefully acknowledged.

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TENDON TRANSPLANTATIONS IN THE LOWER EXTREMITY

A Review of End Results in Poliomyelitis *

II. Tendon Transplantations at the Knee

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INTRODUCTION

Muscle weakness about the knee is a relatively common and serious handicap to patients with poliomyelitis. Tendon transplantation to reinforce a weakened or paralyzed quadriceps femoris muscle offers hope of functional improvement in certain of these patients. In an effort to increase our knowledge in this field, we have reviewed the literature on this subject and have studied the end results of a group of patients with tendon transplantations at the knee followed at the Massachusetts General Hospital.

HISTORICAL REVIEW

From 1881 until about 1895, tendon transplantation was confined to the muscles of the foot. In September 1895, Goldthwait presented a paper at The American Orthopaedic Association meeting in Chicago in which he reported on his four cases of tendon transplantation in the foot. He had undertaken this work in the belief that it was largely original, but had become aware of Nicoladoni's prior contribution after perusal of the literature. Goldthwait pointed out that these same principles might well be applied to other regions of the body, adding that "At the knee, undoubtedly, it could be employed to advantage in a certain limited number of cases . . .". Two years later he described five cases in which he had divided the sartorius tendon near its insertion and had re-attached it to the aponeurosis of the quadriceps extensor above the patella. Three of these patients showed marked improvement. The unsatisfactory results in two cases he attributed to failure of the stitches to hold.

Over the next few years many types of tendon transplantations about the knee were reported. These were apparently uniformly successful, whether the technique was the tendon-to-tendon suture of Nicoladoni or the periosteal implant of Drobnik. Lange, who favored periosteal implantation, described and advocated the operation of bringing the inner and outer hamstrings forward to the tibial tubercle by elongation with silk strands.[9] Later, Lange analyzed his experiences and stated that tendon transplantation in quadriceps paralysis was most successful if a good glutaeus maximus was present.[10] If a good glutaeus maximus was lacking, the calf muscles should be good and the substituting muscles strong.

When Tubby reviewed tendon-grafting in 1912, he found that "The best results have undoubtedly been obtained about the knee joint". His own results were "most encouraging . . . , and in over 40 per cent. . . . complete power of extension in the leg, both in standing and sitting, has followed, and partial power in 50 per cent. of the remainder".

Calot in 1914 observed that the presence of quadriceps paralysis was not in itself a sufficient indication for tendon transplantation. He felt that operation was called for only when a weak quadriceps was associated with intact hamstrings and when this combination resulted in unsafe walking.

In 1931 Crego and Fischer reported sixty-three cases of transference of the biceps femoris tendon to the patella, in sixty of which the results were found to be satisfactory. In 1948 Schwartzmann and Crego again reviewed these cases, adding thirty-seven addi-

* This study was aided by a research grant from the National Foundation for Infantile Paralysis, Inc., and was carried out at the Massachusetts General Hospital.

tional cases to make a combined total of 100 cases. They found that lateral dislocation of the patella had occurred in twenty-nine out of the 100 transplantations. Since 1935 they have been advocating transfer of both the biceps femoris and the semitendinosus forward to the patella, to avoid this complication. Their review also pointed out that certain failures were associated with genu recurvatum, equinus of the foot, and poor calf musculature.

The refinements of tendon transfer owe much to the efforts of Mayer, Biesalski, Steindler, and Ober. As recently as 1933, Ober found that "Surgeons have become so profoundly interested in the excellent results of arthrodesis that only a very few have undertaken to improve and develop a better technique of tendon transplantation". Ober pointed out that there is danger of a hyperextension deformity of the knee developing if the hamstring muscles are transplanted. He noted that the tensor fasciae latae and sartorius are often spared in poliomyelitis and that they may be transplanted to improve extension of the knee. He felt that the anatomical situation of these muscles gives a better physiological action on the patella and better anatomical relation to the anterior structures of the thigh than does a hamstring transplant.

Mayer states that "although it is possible to walk with excellent gait despite paralysis of the quadriceps, the mechanics of weight-bearing are decidedly improved by a shift of two hamstrings to replace the paralyzed extensor muscle. The operation should not be done unless at least four of the hamstrings are fairly strong". He rates the choice of muscles to be transplanted as biceps, sartorius, semitendinosus, and gracilis, in that order. The semimembranosus should not be used, since it is an important factor in preventing hyperextension of the knee. He places major emphasis on the technique of the operation.

In a contemporary survey of transplants at the knee, Kuhlmann and Bell report on cases followed through the Vermont State Crippled Children's Clinics. Although on examination few of the knees showed objective improvement, there was a subjective feeling of increase in stability of the knee in many of the cases.

CLINICAL STUDY

Thirty-eight patients who had had tendon transplantations at the knee between the years of 1922 and 1946 and had been followed at the Massachusetts General Hospital returned for end-result study. The follow-up period averaged nine and two-tenths years. One of the patients had bilateral transplantations, so that thirty-nine knees were available for examination. The sex ratio was nearly equal (eighteen males and twenty females). Age at operation varied from seven to thirty-three years and averaged sixteen and six-tenths years. Eight patients had had operations when they were less than twelve years of age.

INDICATIONS FOR OPERATION

Hospital records rarely contain all the information desired for clinical research, and the records on these cases were no exception to the rule. The indications for operations as recorded were:

"Correction of knee-flexion deformity"	13 cases
"Prevention of knee buckling and falling"	10 cases
"Strengthening knee extension to permit discarding brace"	9 cases
"Strengthening quadriceps"	8 cases

In a few cases multiple indications were noted, but it may be safely assumed that the primary purpose of the transplant in all of our cases was to improve extensor power in the knee.

Malalignment and flexion contractures of the knee were present in thirteen of our cases. Suitable corrective procedures (osteotomy or soft-tissue release) accompanied or preceded the tendon transplantation.

TABLE I

TENDON TRANSPLANTS AT THE KNEE

Type of Transplant	Combined Knee Extensor Power at End Result		Total Cases
	Fair or Better	*Poor*	
Tensor fasciae latae and sartorius	3	11	14
Biceps femoris alone	4	6	10
Tensor fasciae latae alone	2	3	5
Sartorius alone	2	2	4
Tensor, biceps, and semitendinosus	0	2	2
Tensor, sartorius, and semitendinosus	0	1	1
Tensor and biceps	0	1	1
Tensor and semimembranosus	0	1	1
Tensor, biceps, and gracilis	1	0	1
TOTAL Cases	12	27	39
TOTAL Per cent.	30.8	69.2	100

OPERATIVE TECHNIQUE

As may be noted in Table I, all of the available muscles were transplanted in various combinations. The muscles most commonly used were the tensor fasciae latae, sartorius, and biceps femoris.

END RESULTS

End-result study of these cases revealed certain important facts:

1. Of thirty-nine knees which had tranplants, twelve required long braces preoperatively. Seven of these twelve patients discarded their braces after the operation.

2. Twenty-seven of the thirty-nine were still unable to extend the knee against gravity postoperatively, even though about two thirds of these had been rated as *improved*.

3. Those enabled by the operation to extend the knee against gravity were not necessarily able to discard their apparatus. On the other hand, certain patients unable to extend the knee against gravity had good function and were brace-free.

A completely satisfactory method of rating function in the transplant was not attained. In the sitting position, with the hip flexed to a right angle, the biceps transplants usually demonstrated much better power than they did when rated with the hip in extension. The tensor and sartorius transplants on the other hand showed better function with the hip in extension (lying or standing) than they did with the hip in flexion (sitting).

Subjective ratings seemed so unreliable that we were forced to discard statistics in this category. For instance, of five patients who stated that they were improved by the transplantation, one still wore a brace and in two others no power in knee extension could be demonstrated.

It is obvious that there are many factors other than the power of knee extension which affect function of the extremity. One factor is the strength of the other leg. A patient with one strong lower extremity is able to control his weak limb and to walk with much better stability than can the patient who has bilateral weakness.

Another factor is the amount and distribution of muscle power in the affected extremity. The power in the posterior musculature of the hip, the knee, and the calf is of particular importance. In order to study this factor, the thirty-seven patients with unilateral transplantations were divided into three groups.

Group I includes those with a rating of *fair* or better in one or both gluteals, in one or more hamstrings, and either or both the gastrocnemius and soleus. Twenty patients fell into this group. Only six of these twenty (30 per cent.) could extend the knee against

TABLE II
POSTOPERATIVE RESULTS

	Cases	*Per cent.*
Able to extend knee against gravity	12	30 8
Unable to extend knee against gravity	27	69 2
Able to walk without brace postoperatively	34	89 6
Able to walk without brace preoperatively	27	69 2
Patients enabled by operation to discard brace	7 of 12	58 0

gravity, but twelve (60 per cent.) walked without support of any kind. Four used a cane or crutches because of involvement of the other extremity as well. The remaining four patients required a long brace.

Group II includes twelve patients with poor power in one of the three posterior muscle groups and fair or better power in the other two regions. Of these twelve patients, four could extend the knee against gravity and nine of the twelve (75 per cent.) used no support whatever for walking. The other three who required a cane or crutches had bilateral involvement. None needed a brace for the knee which had been operated upon.

Group III included patients who had not more than one posterior muscle group rated *fair* or better. There were only five cases in this group. One could extend the knee against gravity, but still required a brace. Another, unable to extend the knee against gravity, was able to walk without apparatus. Of the five patients, three needed full-length braces, a fourth used crutches with a brace on the opposite leg, and only one patient walked without apparatus.

These statistics emphasize the role of the posterior leg musculature in brace-free ambulation.

We felt that it would be of interest to compare patients with transplantations at the knee with similar patients who did not have transplantations at the knee done. Two control groups with unilateral quadriceps weakness were studied.

Control Group A was made up of patients with *poor* power or less in the quadriceps, who had not had a transplantation at the knee and who did not require a long brace for walking. Thirty-eight cases were found. Of these, twenty-four (63 per cent.) were in Group I (*fair* or better muscle power in all three posterior muscle groups). Eight cases (21 per cent.) were in Group II. Six of the thirty-eight (16 per cent.) were in the Group III classification.

Control Group B included those with *poor* or less quadriceps power, without a knee transplant, but with a long brace. Only seven (9 per cent.) of the seventy-nine patients in this control group belonged to Group I — that is, *fair* or better power in all three posterior muscle groups. Sixty-three cases (80 per cent.) fell into Group III with at least two of the three posterior muscle groups rated *poor*. This inverse correlation with the transplant group is noteworthy.

Of these B Controls, one of the seven patients in Group I and four of the sixty-three in Group III could extend the knee against gravity, but all five still required a long brace for walking out-of-doors.

DISCUSSION

As no two poliomyelitic patients have identical muscle involvement, residual muscle power, and bone and joint structure, it is impossible to compare individual cases. Nevertheless, it is of some significance that we were able to find an identical number of "control cases" with the same patterns of muscle weakness, who had poor quadriceps power and yet were brace-free.

The importance of the stabilizing effect of muscle power about the hip, posterior to the knee, and in the calf has been emphasized earlier in this paper. Additional factors of

great importance are the stability of the foot, ankle, and knee. Any deformity at the knee seriously jeopardizes the success of a knee transplantation. Genu recurvatum, flexion deformity, genu varum, or genu valgum of any significant degree may necessitate the use of a brace, even though power in extension is satisfactory. In similar fashion, deformity or instability of the foot adversely affects knee function, whether a transplant has been done or not. The most successful cases in this series were the seven in which, after tendon transplantations at the knee, the patients were enabled to discard their braces. All of the seven had had other surgery on the affected extremity which undoubtedly had an important effect on the result. If a foot stabilization has been done concomitant with the knee transplantation, one cannot be certain that the transplantation was necessary.

In certain of our cases, the weakened extremities had been carefully protected by splints and braces, because the surgeon assumed that such apparatus was necessary. Such assumptions may be fallacious. Under modern methods of treatment, deformities are prevented; and, by careful functional training, markedly weak extremities may be made to function satisfactorily without braces and without transplants at the knee.

Kinesiology is still an infant science. The normal function of the thigh muscles in activities such as standing, level walking, incline walking, stair climbing, and running is not fully understood. The powerful hamstring muscles have important normal functions which may be impaired by transplanting them.

The crucial test of the value of knee transplants has, we believe, not yet been made. If a series of patients with quadriceps weakness had all other necessary surgery (such as foot stabilizations) completed, and had had adequate gait training prior to muscle transplantation, then, if function were improved following muscle transplantation, one could assume that the operation had definite value. To our knowledge such a series of cases has never been reported. We have observed two patients who had normal musculature except for a totally paralyzed quadriceps femoris muscle. Each of these patients had such good function in the extremity that we felt that tendon transplantation would be of little or no benefit.

We realize that, in the series of cases here reported, we rarely used the "ideal" combination of tendons as recommended by Mayer. This was a matter of necessity rather than of choice. We were forced to use such muscles as were available and which had sufficient power to warrant their transplantation. The ideal case occurs rarely; the difficult problem cases, with marked muscle weakness, occur frequently.

A careful study of this series of cases leads us to believe that we have not been strict enough in selection of cases for tendon transplantation and that we still lack knowledge concerning muscle function which is fundamental to the solution of the individual problems which confront us.

SUMMARY

Early tendon transplantations were confined to the foot following Nicoladoni's original operation in 1881. The knee offered the next logical site for experimentation and Goldthwait in 1897 reported on successful sartorius transplants to strengthen weak quadriceps muscles. Subsequently all the thigh muscles, individually or in combination, have been so employed.

In this end-result study we have evaluated thirty-eight patients in whom thirty-nine transplantations at the knee were done between 1922 and 1946 with an average follow-up of nine and two-tenths years. The subjective results were similar to those in other reports and were in general good, but on objective grounds the results were disappointing.

Knee-extension power following tendon transplantation was rated *fair* or better in only 30 per cent. of the cases. Seven of twelve patients using braces preoperatively were enabled to discard their braces. Even in these apparently successful cases the effect of the tendon transplantation and of other operative procedures could not be evaluated separately.

Comparison of the transplantation cases with control groups with similar patterns of muscle weakness leads us to draw certain important conclusions. The function of the extremity, as well as the ability to walk without apparatus, is dependent on a number of factors. There has been a tendency to assume that the most important factor is quadriceps or extensor power. Our study suggests that other factors are of equal importance. Good hip, posterior thigh, and calf musculature will permit excellent function, even when the quadriceps is paralyzed. On the contrary, the extremity with good quadriceps power and poor posterior musculature usually requires bracing. Good power in extension of the knee is less important in brace-free walking than is a stable foot and good posterior musculature. Tendon transplantation at the knee in some instances impairs function by the production of hyperextension deformities, dislocation of the patella, or lateral instability.

Although a number of cases in this series have apparently been greatly benefited by muscle transplants, others must be rated as *failure*.

The indications for tendon transplantation to improve extensor power of the knee are not easy to formulate. It is our belief that in the past such operations have been done too frequently.

Poliomyelitis has been described as a subtractive disease, and ill-advised tendon transplantation at the knee in some instances is a subtractive operation.

NOTE: The assistance of Miss Anne Dunmore, of the Poliomyelitis Clinic at the Massachusetts General Hospital, is gratefully acknowledged.

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A CLINICAL EVALUATION OF TENDON TRANSPLANTATIONS FOR POLIOMYELITIS AFFECTING THE LOWER EXTREMITIES *†

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INTRODUCTION AND HISTORICAL REVIEW

The problem of restoring active function to paralyzed muscles has interested surgeons for many years. Tendon transplantation, as a means of accomplishing this objective, was first described in 1880 by Nicoladoni, who transplanted the peroneal tendons into the tendo achillis for pes calcaneus resulting from poliomyelitis. Before the turn of the century other cases were reported on the European continent by Hacker, Drobnik, and Codivilla, and in England by Eve. Meanwhile in America, in 1895, Milliken first described a method of partial transference of the extensor hallucis longus tendon to the paralyzed tibialis anterior muscle as shown in Figures 1-A, 1-B, and 1-C. In the same year Goldthwait read a paper, with a review of the literature, on tendon transplantation in the treatment of paralytic deformities.

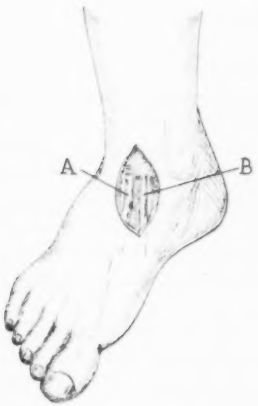

FIG. 1-A

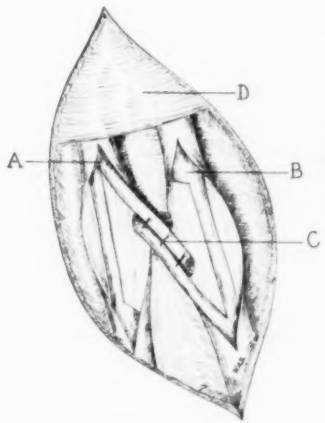

FIG. 1-B

FIG. 1-C

Fig. 1-A: *A*, tendon of extensor hallucis longus; *B*, tendon of tibialis anterior. (After Milliken.)
Fig. 1-B: *A*, tendon of extensor hallucis longus; *B*, tendon of tibialis anterior; *C*, flaps are united with interrupted sutures; *D*, annular ligament of the ankle. (After Milliken.)
Fig. 1-C: Sheaths of the tendons are united with continuous suture. (After Milliken.)

During the early part of the twentieth century, owing perhaps to poor selection of cases or to unsatisfactory techniques, the operation of tendon transplantation fell into disrepute, particularly in America. Dr. Royal Whitman, in an address before The American Orthopaedic Association in 1903, pointed out that those who had had considerable experience with the operation and who had had the opportunity to analyze the results would readily admit that tendon transplantation, at least in its original form, was a disappointment. In Europe, however, tendon transplantation was being advocated by staunch

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TABLE I
TENDON TRANSPLANTATIONS FORWARD

Tendons	Combined Good plus Excellent Rating (*Per cent.*)
Tibialis anterior	80
Peroneus longus	61 6
Peroneus longus and peroneus brevis	33 3

TABLE II
TENDON TRANSPLANTATIONS BACKWARD

Tendons	Combined Good plus Excellent Rating (*Per cent.*)
Peroneus longus and tibialis posterior	66 6
Peroneus longus	40
Peroneus longus and peroneus brevis	28 6

supporters, such as Vulpius and Lange, who, although differing to some extent in their techniques, were united in their enthusiasm for this operation.

Later in this century, as the limitations of the transplantation procedure became better recognized and the techniques of operation were improved, the method gradually returned to favor. Significant developments in the technique were described by Biesalski, Mayer, Jones, Lovett, Steindler, Ober, and others, with the result that the techniques for tendon transplantation have now become well standardized. There persists, however, a general belief, at least in many parts of this country that, in the case of transplantations about the ankle, better results are obtained when these transplantations are accompanied by tarsal arthrodesis; this belief was expressed in 1923 by the Commission appointed by The American Orthopaedic Association for the Study of Stabilizing Operations on the Foot.

The results of tendon transplantations have been published from time to time. Kleinberg and Zadek, in 1918, reviewed a series of transplantations about the foot and ankle, as did Steindler in 1919. More recently, interest in transplantations about the knee has been indicated by the reports of Colonna, Crego and Fischer, Schwartzmann and Crego, and Broderick, Reidy, and Barr.

METHOD AND MATERIAL

Our own study began with a desire to ascertain the results of tendon transplantations performed for residual poliomyelitis in Vermont, from the standpoint of each individual patient in his every-day life. For practical reasons it seemed advisable to confine this study to transplantations about the knee, ankle, and foot. We decided to base our data upon a personal interview and an examination of each patient by one of the authors, supplemented by a manual muscle test. The findings were then recorded on individual data sheets, preparatory to analysis.

In this study we were aided greatly by the Poliomyelitis After-Care Program which has been active in Vermont since the epidemic in 1914. Established with the help of Dr. Lovett and carried on by Dr. Ober, this program has furnished orthopaedic care to a high percentage of Vermont's poliomyelitic patients, thus ensuring an unusual degree of uniformity in selection of cases for surgery and in operative techniques. Excellent

records on all of these patients have been maintained throughout the years, at first by the After-Care Program and later by the Crippled Children's Division of the Vermont State Department of Health, which developed as an expansion of the former program. The size and character of the state and its population were also significant factors in accomplishing such a relatively high percentage of follow-up examinations, especially so many years after surgery. Without the co-operation and interest of the patients themselves, this study would have failed.

The case records of 1,555 patients with paralytic poliomyelitis, extending over a period of approximately thirty-five years from 1914 to 1949, were reviewed. Among these cases were found 255 patients, or 16.4 per cent. of this total, who had had one or more tendon transplantations about the knee, ankle, or foot. It was possible to interview personally and to examine 162 patients, or 63.5 per cent. of the 255 patients with these transplantations. Of the ninety-three patients who were not examined, seventy-five had moved out of the state or had otherwise been lost to follow-up, ten did not wish examination, and eight were known to have died. In 103, or 63.6 per cent., of the 162 patients seen, the follow-up period was for sixteen to thirty years after surgery (Chart I). The entire group of 162 patients represented some 395 separate tendon transplantations, many of which had been accompanied by adjuvant procedures, such as heel-cord lengthening, plantar fasciotomy, tenodesis, and stabilization operations, particularly tarsal arthrodesis. The techniques used in these transplantations were much the same as those which are standard today.

CLASSIFICATION OF RESULTS

In order to evaluate the results in these 395 tendon transplantations, an effort was first made to compare the postoperative with the preoperative situation for each individual. From records and, if possible, from the patient's memory, the anatomical deformity, muscle weakness, and functional limitation existing before operation were noted; these were then compared with the situation as found in our examination. From this comparison, an attempt was made to evaluate the effectiveness of each transplantation in actively alleviating the deformity, in restoring muscle strength, and in producing functional improvement. The degree to which the desired result had been accomplished was estimated for each transference; the latter was then classified according to an arbitrary scale, in which *poor* represented less than 25 per cent. success in effectively reducing deformity and in actively improving function; *fair*, 25 to 50 per cent.; *good*, 50 to 75 per cent.; and *excellent*, 75 to 100 per cent. This method of analysis, although useful in preparing tables (Tables I and II), did not seem adequate for the presentation of our findings, and hence the latter have been organized here on a more descriptive basis.

To facilitate this analysis, the tendon transplantations were arbitrarily divided into three categories:

1. Tendon transplantations about the knee, which included those for quadriceps insufficiency (thirty-two patients with sixty-three transplantations);

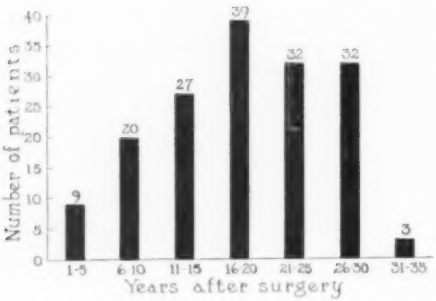
2. Tendon transplantations at the ankle, which included all the tendons crossing the ankle joint except the long extensors of the toes (125 patients with 205 transplantations);

3. Tendon transplantations in the foot, which included the extensor hallucis longus and extensor digitorum longus tendons (sixty-four patients with 127 transplantations).

That the number of patients enumerated in the three categories totals 221 instead of 162 is due to the fact that some of the patients had transplantations in more than one of the three categories.

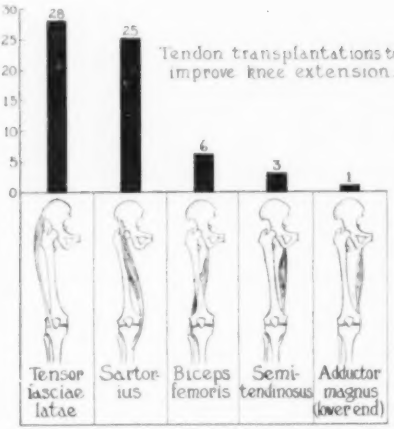
Tendon Transplantations about the Knee

The group which had transplantations about the knee consisted of thirty-two patients upon whom sixty-three separate tendon transferences to overcome quadriceps



Follow-up record of tendon transplantation operations.

CHART I



Number of times each tendon used whether singly or in combination.

CHART II

insufficiency were done. Although small, this group of patients demonstrated certain definite results. The tensor fasciae latae and sartorius tendons were transplanted most frequently in combination and singly (Chart II). Despite the apparently superior anatomical position of these two tendons in contradistinction to the anatomical position of others, such as the biceps femoris, the poorest functional results were obtained when these were used, particularly in transplantations of the tensor fasciae latae. The transferences of the biceps femoris tendon, although few in number, gave better functional results. No instances of lateral displacement of the patella were reported in six transplantations.

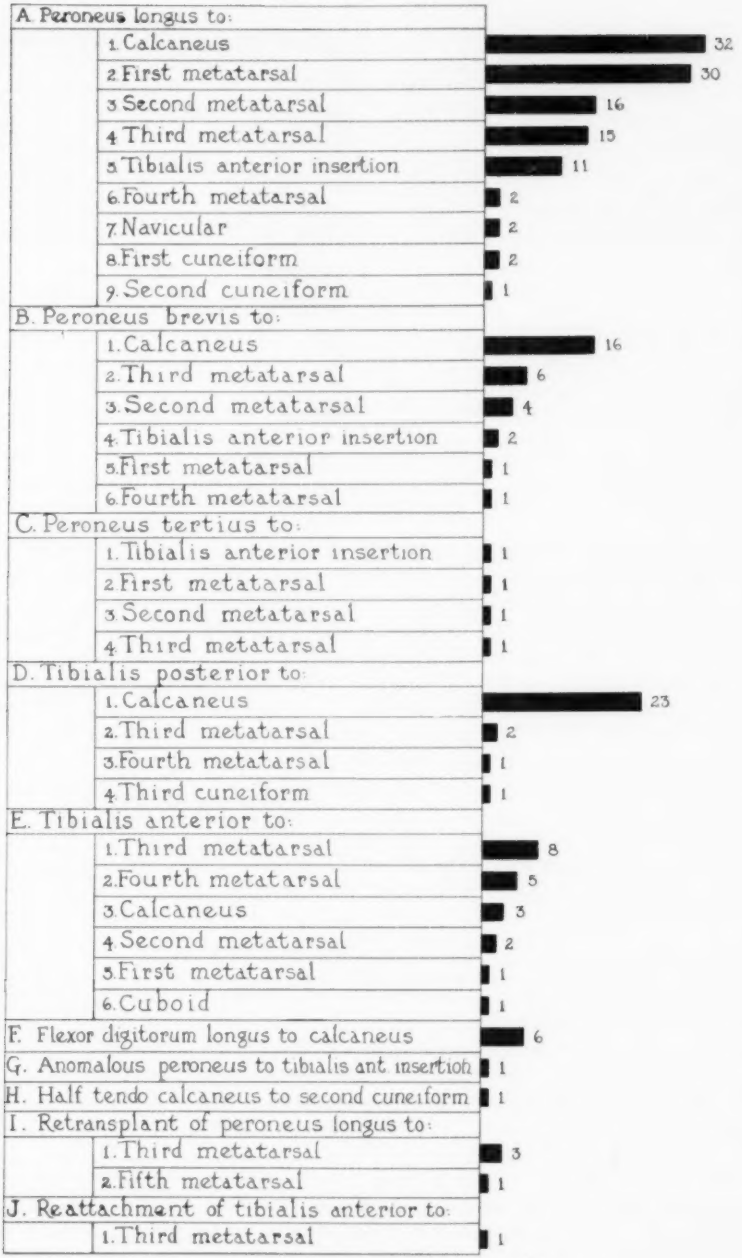
Objectively, the entire group was disappointing in the degree of active extension achieved against gravity. Subjectively, however, most of the patients were satisfied with their transplantations at the knee because of a sense of increased stability which the operation apparently afforded them.

Tendon Transplantations at the Ankle

Tendon transplantations at the ankle arbitrarily included all of the tendons crossing the ankle joint with the exception of the extensor hallucis longus and the extensor digitorum longus. This group, the largest of the three, consisted of 125 patients with 205 operations. Chart III demonstrates the number of times each particular muscle was used and the point of new insertion.

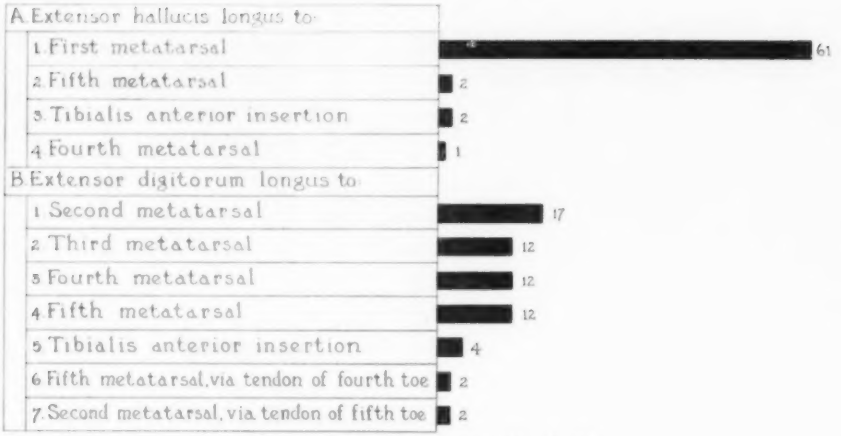
The peroneus longus tendon was transplanted most frequently, being moved anteriorly onto the dorsum of the foot to aid dorsiflexion insufficiency, and posteriorly onto the calcaneus to aid plantar-flexion weakness. The peroneus longus muscle functioned satisfactorily, both when transplanted forward and inward to the area of the insertion of the tibialis anterior and when transplanted to the shaft of the first metatarsal. The transferred tendon also functioned well when placed into the region of the base of the second and third metatarsals. In four instances it was necessary to re-transplant the peroneus longus tendon which had been anchored in the area of the insertion of the tibialis anterior muscle, because it tended to pull the foot into a varus position despite tarsal arthrodesis. On the whole, the tendon functioned better when placed in the region of the mid-portion of the foot than it did when brought over and placed into the area of the base of the first metatarsal.

The peroneus longus tendon was also transplanted posteriorly into the calcaneus to aid gastrocnemius and soleus insufficiency. The best results in these posterior transferences came with the use of both the tibialis posterior and the peroneus longus tendons, particularly when associated with tarsal arthrodesis (Table II).


A. Peroneus longus to:
1. Calcaneus 32
2. First metatarsal 30
3. Second metatarsal 16
4. Third metatarsal 15
5. Tibialis anterior insertion 11
6. Fourth metatarsal 2
7. Navicular 2
8. First cuneiform 2
9. Second cuneiform 1
B. Peroneus brevis to:
1. Calcaneus 16
2. Third metatarsal 6
3. Second metatarsal 4
4. Tibialis anterior insertion 2
5. First metatarsal 1
6. Fourth metatarsal 1
C. Peroneus tertius to:
1. Tibialis anterior insertion 1
2. First metatarsal 1
3. Second metatarsal 1
4. Third metatarsal 1
D. Tibialis posterior to:
1. Calcaneus 23
2. Third metatarsal 2
3. Fourth metatarsal 1
4. Third cuneiform 1
E. Tibialis anterior to:
1. Third metatarsal 8
2. Fourth metatarsal 5
3. Calcaneus 3
4. Second metatarsal 2
5. First metatarsal 1
6. Cuboid 1
F. Flexor digitorum longus to calcaneus 6
G. Anomalous peroneus to tibialis ant. insertion 1
H. Half tendo calcaneus to second cuneiform 1
I. Retransplant of peroneus longus to:
1. Third metatarsal 3
2. Fifth metatarsal 1
J. Reattachment of tibialis anterior to:
1. Third metatarsal 1

Tendon transplantations to the ankle.
125 patients — 205 operations

CHART III



Tendon transplantations to the foot.
64 patients—127 operations

CHART IV

The peroneus brevis tendon, although valuable as a substitute for the peroneus longus, did not appear to be as successful a transplant as its mate. The peroneus tertius tendon, which was transplanted only rarely, was an ineffective transference.

The "natural" tendon transplantation about the ankle was the relocation of the tibialis anterior tendon onto the dorsum of the foot. This was used to aid dorsiflexion weakness and to alleviate varus deformity of the metatarsus. It proved to be the most reliable type of tendon transplantation with a *good* plus *excellent* rating of 80 per cent. (Table I). However, there were technical difficulties even with this transplantation. On two occasions the tibialis anterior tendon was found to function strongly when originally transplanted into the base of the third metatarsal; but after about six months, it had become firmly attached to the extensor longus tendon sheath, so that its action was actually that of the tendon to which it had become attached.

The flexor digitorum longus tendon was an effective transplant when it was transferred into the calcaneus, but it did not function as effectively as the peroneus longus and tibialis posterior tendons.

Tendon Transplantations in the Foot

The sixty-four patients with tendon transplantations in the foot represented 127 operations involving the long toe extensors, mainly to overcome "cock-up" deformities of the great and lesser toes. The tendons used in this group, the extensor hallucis longus and the extensor digitorum longus, were usually transferred to the respective metatarsal neck or shaft of the affected toe, the extensor hallucis longus being the tendon transplanted more frequently (Chart IV). Occasionally this tendon was placed into the insertion of the tibialis anterior muscle.

The extensor hallucis longus tendon, like the tibialis anterior, rarely lost power during transference. On the other hand, it demonstrated an inordinate tendency to become attached to the sheaths of neighboring tendons, or re-attached to the base of the distal phalanx of the great toe. Although this transplantation usually overcame the "cock-up" deformity of the great toe, the transplants which gave poor results were those tendons which had re-grown down the old sheath and had become re-attached to the proximal portion of the distal phalanx. The muscle itself appeared to be too small in

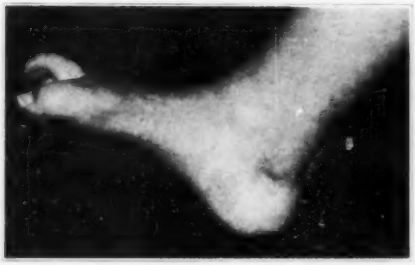


FIG. 2

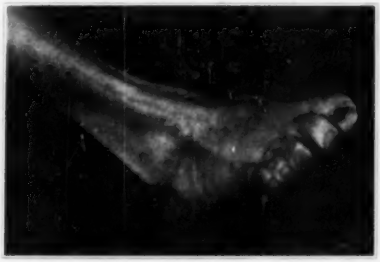


FIG. 3

Fig. 2: Shows "dorsal-bunion" deformity of the right great toe, following transplantation of extensor hallucis longus tendon into the neck of the first metatarsal, associated with transfer of the peroneus longus to the calcaneus and tarsal arthrodesis. The flexor hallucis longus and the flexor hallucis brevis remained strong. The original deformity was a "cock-up" deformity of the great toe. Photograph was taken six years after surgery.

Fig. 3: Demonstrates the effective synergistic action of the lateral long toe extensors to aid the transplanted and strongly functioning peroneus longus tendon in dorsiflexion action of the foot. Note the effective peroneus brevis tendon despite tarsal arthrodesis, performed twenty-seven years previously.

volume to act as an effective substitute for the tibialis anterior tendon. When, however, it was combined with another effective muscle transplant, such as the peroneus longus attached to the inner aspect of the first metatarsal, the action of the absent or weakened tibialis anterior muscle could be simulated.

The extensor hallucis longus was, on the whole, an effective transplant, but great care apparently was required to keep the tendon from adhering to the surrounding tendon sheaths, or from re-growing down the old tendon sheath to its original place of insertion. Occasionally a "cock-up" deformity of the great toe was exchanged for the equally uncomfortable deformity of a "dorsal bunion". The deformity apparently resulted from the augmented pull on the first metatarsal by the proximally transplanted extensor hallucis longus and a functioning tibialis anterior in the face of a strong flexor hallucis brevis and a paretic or transferred peroneus longus tendon (Fig. 2).

The extensor digitorum longus was likewise usually transplanted to the neck of the metatarsal of the affected toe, but this transplant attained a lesser degree of functional improvement than was the case in the extensor hallucis longus. This may, of course, be a reflection on the inability of simple recession of the tendon to simulate the action of the weakened lumbrico-interosseus mechanism, which apparently contributes to the "cock-up" deformity of the lesser toes.

ADDITIONAL CLINICAL OBSERVATIONS

1. The problem of the amount of muscle strength lost during tendon transference has long interested orthopaedic surgeons. In this study, the peroneus longus muscle in its transplantation anteriorly to the dorsum of the foot was selected for comparison. It was found that approximately 40 per cent. of these transplanted tendons lost some degree of muscle power in transference. On the other hand, the so-called "naturals", such as the tibialis anterior and the extensor hallucis longus muscles, rarely seemed to lose any strength.

2. Another observation concerned muscle function after bone stabilization, such as tarsal arthrodesis. Was muscle strength retained in spite of the presumed loss of functional activity of the muscle through arthrodesis? Clinically the peroneus muscles apparently retained considerable strength despite tarsal arthrodesis. This was particularly true of the peroneus brevis tendon, which acted as a deforming element in spite of arthrodesis, exhibiting a definite tendency to swing the metatarsal region into a valgus position (Fig. 3). This observation tended to confirm the impression that, unless the foot was adequately balanced both on the lateral and medial sides, the tendons left at their normal

FIG. 4-A FIG. 4-B

Fig. 4-A: Transplantation of strong peroneus longus and tibialis posterior tendons to the right calcaneus to reinforce a *poor* gastrocnemius muscle. Photograph taken nineteen years after operation.

Fig. 4-B: Effective "tiptoe-standing" on the involved right side due to transferred peroneus longus and tibialis posterior tendons assisted by the balanced normal left foot. Atrophy of the right calf muscles persists.

insertions were capable of acting as deforming elements after arthrodesis. These tendons apparently retained strong muscle pull capable of causing bone deformity in the growing foot or recurring deformity in spite of bone stabilization operations.

3. From the standpoint of function, the end result of a tendon transplantation relied as much upon the strength and function of the neighboring tendons as it did upon its own strength. Although the extensor hallucis longus tendon was not a strong enough tendon to substitute for the action of the paralyzed tibialis anterior muscle, yet, when it was reinforced by a strongly functioning peroneus longus transplant, it was able to perform satisfactorily for the paralyzed muscle. The lateral long toe extensors also appeared to be helpful in the functional result obtained by tendon transplantation to the dorsum of the foot (Fig. 3).

Although the synergistic action of tendons was usually helpful, at times it became overwhelming. This was particularly true if the transplanted tendon was placed somewhat loosely into its new insertion. Substitution action of the strong neighboring tendons was so great that the transplanted muscle could not function independently. This was illustrated by a case of dorsiflexion weakness in which the extensor hallucis longus overwhelmed the peroneus longus tendon, after it had been transplanted into the region of the insertion of the paralyzed tibialis anterior tendon. Occasionally it was found that the dorsiflexion action of the extensor digitorum longus inhibited the function of a laterally transplanted tibialis anterior muscle. In these cases functional training with particular emphasis on awareness of tendon transplantation becomes especially desirable. The tension under which the transplantation is anchored at time of operation is also important.

4. Another observation is related to the efficacy of posterior transplantations at the ankle and their effect on the strength and development of the calf muscles. Tendon transferences into the calcaneus were reasonably effective, particularly when associated with a tarsal arthrodesis. However, none of the patients could actively rise up on tiptoe, bearing full weight on the involved foot alone. In only one case, in which the tibialis posterior and peroneus longus tendons were transplanted into the right calcaneus, nineteen years previously, could the patient stand almost on tiptoe without assistance (Figs. 4-A and 4-B). As illustrated, he still required "finger-tip assistance" to achieve this tiptoe position; atrophy of the calf muscles remained prominent. In walking, however, this patient manifested an excellent push-off in his gait.

5. Regarding the choice of surgical procedure—that is, the comparative desirability of arthrodesis with tendon transplantation or of tendon transplantation alone—the func-

FIG. 5-A

FIG. 5-B

Preoperative varus of left foot in an eight-year-old boy was due to a *good* tibialis anterior muscle in contrast to weak toe extensors.

FIG. 5-C

FIG. 5-D

Same patient fifteen months after operation. Correction was obtained by the transfer of the tibialis anterior tendon to the third metatarsal, with plantar fasciotomy as the only adjuvant procedure.

tional result was superior when tendon transplantation was associated with a bone stabilization operation, particularly a tarsal arthrodesis. On the other hand, the neutralization of a deforming muscle pull by transplantation was very useful in exerting some control over a progressive deformity, particularly in children (Figs. 5-A through 5-D). In a number of patients with primary tendon transplantations, a subsequent arthrodesis was required before good functional results were obtained.

CONCLUSIONS

Any reported investigation would be remiss not to reiterate the general principles of tendon transplantation which have been carefully formulated by earlier observers. This study confirms many of these principles, and they are here recounted:

1. *Proper selection of cases:* It seems wise to wait at least twelve months, preferably from eighteen to twenty-four months, after the onset of poliomyelitis before tendon transplantation is considered. The passage of time will delineate the muscle strength of the individual muscle groups. Unless the deforming pull is a pernicious force, causing a rapidly progressive deformity, it seems inadvisable to transplant any tendon in a patient younger than five years of age. The proper selection of the tendons to be transferred, in regard to their strength, size, and anatomical position, is mandatory.

2. *Correction of fixed deformities:* Any existing deformity must be corrected, preferably prior to, or at least concomitant with, the tendon transplantation, either by manipulation, ligamentous procedure, or bone operation.

3. *Adherence to standard operative plans and techniques:* The operative plan should be simple. Complicated tendon transference and multiplicity of tendon transplantation should be avoided. The delicate handling of the tendon during the operative procedure with preservation of the peritenon and with transplantation to the new insertion through a tendon sheath seems highly desirable. The straight-line pull of the transferred tendon should be firmly anchored to bone, reinforced by the overlying periosteum, and with just the "right amount" of tension to hold securely the part in the corrected position.

4. *Attention to postoperative fixation and care:* This should be sufficiently long to allow firm fixation of the transplanted tendon to occur; at least three, and usually six weeks are necessary.

5. *Attention to convalescent protection and care:* Continued protection of the transplanted tendon by a suitable orthopaedic appliance worn during the day with a protective splint or a retention cast at night seems desirable for a six months' period. Protective shoe corrections for an additional six months will prove advantageous. Functional exercises for the transplanted tendon should be encouraged as soon as firm fixation has taken place and should be checked clinically at regular periods.

The results of this clinical study seem to indicate that, with the exception of the group with tendon transplantations about the knee, in which objective improvement was slight, tendon transference, as performed in the region of the ankle and foot, particularly when combined with tarsal arthrodesis, is a feasible and successful orthopaedic procedure. It should be emphasized that the success of the procedure depends upon the proper selection of cases and the rigid adherence to the other criteria for tendon transplantation.

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DISCUSSION

Dr. Thomas Gucker, III, Warm Springs, Georgia: A long-term follow-up of the number of cases which the authors have presented is essential to a clear understanding of what one can expect from tendon transfers in poliomyelitis. Of necessity, because of time, Dr. Kuhlmann was unable to take up some of the items which he wished to include and had to confine himself in large part to generalities. As you well know, the treatment of poliomyelitis requires meticulous attention to a number of details; I would like to consider a few more specific aspects of these problems.

In general, our findings at the Georgia Warm Springs Foundation are very much in agreement with those of the authors'. It has been our experience too that, generally speaking, it is unwise to consider tendon transferences early in poliomyelitis; it is preferable to wait eighteen months or longer after the onset of paralysis and until the child is over five years of age. Dr. Kuhlmann implied and we also would like to emphasize the special consideration of a rare case in which there may be almost total absence of power in the gastrocnemius soleus in combination with nearly normal power in the tibialis anterior, tibialis posterior, peroneals, and toe extensors. We are then dealing, of course, with the problem of progressive calcaneus and the very great difficulty of trying to control it by the usual conservative means of manipulation, retention splints, or braces. For that reason, therefore, it might be well to consider, as early as a year after onset, transference of the strongest of the deforming tendons posteriorly to the os calcis, even a number of years in advance of the age for stabilization. At the proper age, stabilization by triple arthrodesis will be necessary in all probability and, in addition, at that time the appropriate remaining tendon transferences can be done.

The second consideration concerns the selection of the tendon for transference. The authors concluded that the peroneus longus functioned effectively when transferred to the dorsum of the foot to replace a weak tibialis anterior or when moved posteriorly to the os calcis for calcaneus deformity.

May I present to you a problem that occasionally arises, which we find most difficult to analyze,—specifically, the patient who has a partial foot-drop in combination with poor take-off, due to weakness of the gastrocnemius soleus group. In its most extreme form, we have found the analysis of this situation difficult when presented by a patient who has a tendo achillis contracture, and, therefore, an equinus which masks the truly deficient power of the gastrocnemius. The fixed equinus deformity mechanically facilitates the plantar-flexion power of the peroneals. In other words, one may be impressed with the drop-foot element in the gait with the fixed equinus and proceed to deal with that primarily. In several instances we have observed patients who were treated for a fixed equinovalgus deformity of the foot by heel-cord lengthening, stabilization by triple arthrodesis, transference of both peroneals to the anteromedial tarsus, and who then presented a calcaneovarus deformity, which was more disabling than the equinovalgus. When the difficulties of evaluating the power of the gastrocnemius are so great, it is our present recommendation that, if adequate or even reasonably fair toe-extensor power remains to help dorsiflex the foot, and especially when heel-cord lengthening is necessary, it is wiser as a rule to transfer the peroneals to the os calcis and in that way to avoid development of talipes calcaneus. This is particularly important when there is concomitant quadriceps weakness which is all the more exaggerated by a calcaneus gait. In conclusion, I would like to express the sincere hope that the data which the speakers have presented will be made available to all of us for further consideration, since great benefit can be derived from it, especially by the younger men.

AN EXTRA-ARTICULAR ARTHRODESIS OF THE SUBASTRAGALAR JOINT FOR CORRECTION OF PARALYTIC FLAT FEET IN CHILDREN *

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The structural and functional characteristics of the foot are determined by the integral relation of the osseous architecture of the foot, the relative strength of the supporting ligamentous and capsular structures, the muscle balance about the foot, and the functional stress brought to bear upon the foot. Considerable discussion might be provoked in an attempt to assign the relative role of each factor in the mechanics of the normal foot. In an individual foot, however, where there has been marked disturbance of one of these factors, it may not be too difficult to interpret the mechanism of the resultant deformity. This has been particularly true of the deformities of the foot which develop as a result of muscle imbalance caused by anterior poliomyelitis.

It is the purpose of this paper to discuss the severe valgus deformity which has developed in children who have had paralysis of the anterior and posterior tibial muscles. All of these patients have been young children who have been followed since the onset of the acute illness, and the development of the progressive valgus deformity has been recorded by photographs and roentgenograms. In some instances, the foot on the opposite side has been normal and has served as a control for comparison. The mechanism of this deformity and a method of operative correction will be presented.

Initially the deformity is similar in appearance to that of a mildly pronated foot. There is slight eversion of the heel, moderate prominence of the head of the astragalus (talus) medially, and abduction of the metatarsus. Unlike the pronated foot with good musculature, the paralytic valgus foot usually becomes progressively worse. It is difficult to prevent the development of this deformity by the use of supportive apparatus, such as arch supports, braces, or casts. There are several factors entering into the progressive character of this type of foot deformity. The deformity is initiated by muscle imbalance which displaces the tarsus in valgus and depresses the arch. The functional stress of walking increases the deformity. Inasmuch as these patients are in the actively growing period, the subsequent growth of the bones in the abnormal position increases and fixes the altered contour of the mid-tarsal structures. In a few years the foot may assume the appearance of a very flat foot.

It is easier to understand the mechanism of the paralytic flat foot if the following relations of the normal foot are borne in mind. The position of the astragalus (talus) is relatively fixed, and motion occurs only in the sagittal plane. The movement of the foot into eversion and abduction occurs through the mid-tarsal joints. Since the astragalus is fixed in position, the greatest changes occur at the articulations with the astragalus—the astragaloscaphoid and calcaneo-astragalar joints. Although we speak of abduction and eversion as independent motions, they are concomitant motions. The arc of motion through the subastragalar joint is such that, as the calcaneus is everted, it also moves posteriorly in respect to the astragalus. Unless disruption of the calcaneocuboid joint occurs, the cuboid must become displaced posteriorly as the metatarsus is abducted. In the normal weight-bearing position, the astragalus is in slight equinus and deviated medially about 15 degrees, and the calcaneus is in slight dorsiflexion and deviated 15 degrees laterally. The position of the astragalus is dependent upon the adjacent bones and capsular structures, since there are no muscles inserted directly into it. Posteriorly the body of the astragalus rests squarely upon the superior aspect of the calcaneus, but anteriorly the

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FIG. 1-A

Medial aspect of normal foot. Posterior tibial passing beneath calcaneoscaphoid ligament and supporting astragalus.

FIG. 1-B

Medial aspect of flat foot. Astragalus (talus) in equinus. Calcaneoscaphoid and deltoid ligament stretched.

head of the astragalus is held less securely, since only the lateral aspect of the astragalus and the medial aspect of the os calcis (calcaneus) are in contact. The head of the astragalus is cradled between the sustentaculum tali and the anterior articular surface of the calcaneus. It is apparent that the plantar calcaneoscaphoid ligament and the posterior tibial tendon which passes directly beneath it contribute appreciably to the stability of this articulation. Since the posterior tibial muscle inverts the foot, it helps to keep the sustentaculum tali in position beneath the head of the astragalus. The posterior tibial, in fact, has a slip of tendon which inserts into the sustentaculum tali, although the major insertions are to the scaphoid (navicular), the cuboid, the three cuneiforms, and the second, third, and fourth metatarsal bones. The flexor hallucis longus tendon provides some reinforcement

FIG. 2-A

Lateral aspect of normal foot. The sinus tarsi is open. Astragaloscaphoid (talonavicular) and calcaneocuboid joints are at almost the same level.

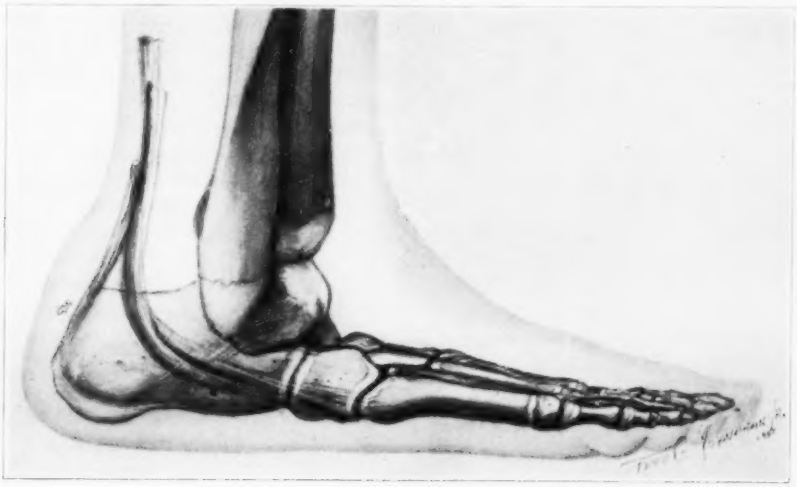

FIG. 2-B

Lateral aspect of flat foot. The sinus tarsi is obliterated. The calcaneus is everted and displaced backward.

as it passes beneath the sustentaculum, but its peripheral insertion decreases its effectiveness (Fig. 1-A).

In the foot with paralysis of the posterior tibial alone or in conjunction with the anterior tibial muscle, the heel is displaced into eversion by the unopposed action of the peroneal muscles and the gastrocnemius. As the calcaneus is everted, its anterior portion is displaced laterally and posteriorly. As a consequence, there is loss of the normal support beneath the head of the astragalus, which drops into equinus and projects further

anteriorly (Fig. 1-B). The backward displacement of the calcaneus and the forward movement of the astragalus results in abduction of the metatarsus (Figs. 2-A and 2-B). Initially this deformity can be corrected by passively inverting the calcaneus and bringing the anterior portion forward and medially beneath the head of the astragalus. If the deformity has persisted for a long period, secondary adaptive changes have occurred which have fixed the deformity and prevent restoration. The most significant of these changes are contractures of the tibio-astragalar joint capsule, shortening of the tendo achillis, contractures of the mid-tarsal joints, and adaptive changes in osseous structure associated with growth.

The surgical correction of this deformity is for the purpose of obtaining several major objectives. The calcaneus must be replaced beneath the astragalus and maintained in normal relation to it. The astragalus must be brought up out of equinus. Muscle balance should be restored by tendon transplantation to avoid recurrence. The deforming everting power of the peroneal muscles should be removed and active inversion and dorsiflexion should be restored to the astragaloscaphoid (talonavicular) area. Since it is desirable to correct this deformity in the young child before it has become fixed, the operative technique should not interfere with subsequent growth of the foot.

HISTORICAL REVIEW

In 1879, E. Albert of Vienna performed an arthrodesis of the ankle joint to stabilize a paralyzed foot, and in 1905 Nieny operated upon the mid-tarsal joints to produce ankylosis. Gwilym G. Davis independently reported a similar operation shortly after this, in which fusion of the joints was accomplished by roughening the adjacent articular surfaces. In 1916 Willard reported a series of patients whom he and Davis had treated by this technique during the previous nine years. He clearly defined the principles of correcting lateral deformities of paralytic feet. He stressed the importance of establishing muscle balance and discussed the problem of growth.

Since these early reports, a myriad of procedures have been described for arthrodesis of the ankle and mid-tarsal joints. There have been two well documented historical reviews of these procedures presented by Hart in 1937 and Schwartz in 1946. Both of these reviews are deserving of consideration by anyone interested in this problem. In this paper the various procedures will be considered in only a general manner as related to the particular problem of the paralytic valgus foot.

In the young child attempts have been made to obtain surgical correction of the paralytic flat foot without arthrodesis of the mid-tarsal joints. The various techniques recommended for correction of pronated feet have been applied to this deformity with some degree of success. It is apparent that there is much variation in the severity of the deformity, depending upon the general ligamentous support, the age of the patient, and the degree of muscle imbalance. Some of the milder deformities may be corrected by procedures to reconstruct the ligamentous support of the longitudinal arch and tendon transplants to provide support to the astragaloscaphoid region. In our experience, these procedures have improved function, but have failed to restore satisfactory alignment of the foot in most instances.

The most successful procedure for the correction of the deformity in older individuals has been the triple arthrodesis, in which bone is resected to correct the deformity. In the young child, however, this would interfere too much with the subsequent growth of the foot. If arthrodesis is deferred until the major portion of growth has occurred, there is usually marked progression in the severity of the deformity. The os calcis (calcaneus) becomes displaced laterally, and the astragalus is in so much equinus that considerable bone must be removed to restore proper alignment. Occasionally the foot remains laterally displaced in respect to the ankle joint. This produces a foot with satisfactory weight-bearing, but one which is difficult to fit with a shoe.

The problem of obtaining fusion of the subastragalar joint without disturbing the relationship of the other mid-tarsal joints is not new. In recent years, however, there has been renewed interest in the arthrodesis of only the subastragalar joint to correct various abnormalities of the foot. In 1943 Leavitt reported his experiences in the treatment of pronated feet by simple arthrodesis of the subastragalar joint. He used the technique of roughening the adjacent articular surfaces originally used by Albert and Davis. In 1946, Chambers discussed the disturbed relations of the astragalus and calcaneus in pronated feet and described an operation to limit the increased abduction of the calcaneus at the subastragalar joint. He lifted up the lateral aspect of the posterior articular surface of the calcaneus with an osteotome and inserted a wedge graft beneath the articulation. This procedure alone is inadequate to maintain correction in the severely pronated paralytic foot.

Gallie described, in 1943, an arthrodesis of the subastragalar joint in which he used a tibial graft inserted across the posterior articular surface. This procedure would seem to be adapted to the paralytic valgus foot, but Dr. Gallie makes it clear "that no attempt has been made in this operation to change the relation of the astragalus to the os calcis or to correct any deformity of the foot. If such were necessary, some different operation would be required". It is our impression that this operation would interfere with subsequent growth, and it has the disadvantage of not allowing visualization of the deformity. Each of these operations serves well in the particular situation for which it was developed, but none of them meets the requirements established for the correction of the paralytic flat foot.

Previously it has been stated that the initial concern in correction is the restoration of the normal alignment of the calcaneus and the astragalus; and the correction of the plantar flexion of the astragalus must follow rather than precede this restoration. If the foot is brought into dorsiflexion before the calcaneus has been replaced beneath the astragalus, no force can be brought to bear upon the head of the astragalus, and it will remain in equinus. The deformity of the foot would be increased as the foot was dorsiflexed, since the calcaneus would be displaced into more eversion. If the astragalus is

FIG. 3-A

FIG. 3-B

FIG. 3-C

Fig. 3-A: Lateral roentgenogram with patient standing shows astragalus in equinus and calcaneus everted and displaced posteriorly.

Fig. 3-B: Shows sinus tarsi opened. Calcaneus has been partially restored beneath the astragalus.

Fig. 3-C: Grafts have been placed in sinus tarsi. Normal relation has been restored.

allowed to remain in equinus and the rest of the foot is displaced into plantar flexion and then inverted and adducted, good alignment can be obtained. Roentgenograms made of the foot in this position will show that normal relations between the astragalus and calcaneus have been restored (Figs. 3-A and 3-B). It will also be noted that the height of the tarsus has been restored and the sinus tarsi, which had been obliterated in the valgus position, is again open. A logical method of maintaining the corrected position becomes apparent. If a wedge could be placed in the sinus tarsi between the inferior aspect of the astragalus and the superior aspect of the calcaneus, the latter could not be everted and the foot would not pronate. The use of bone grafts in this area would provide an excellent mechanical block and yet would be essentially an extra-articular arthrodesis (Fig. 3-C). The height of the foot would be restored, and subsequent growth would not be disturbed. The final objectives in correction could be obtained by transferring one of the peroneal tendons to provide dorsiflexion and support to the longitudinal arch if indicated. This is the procedure which has been used in correcting the paralytic flat foot for the past six years.

OPERATIVE TECHNIQUE

A short curvilinear incision is made on the lateral aspect of the foot directly over the subastragalar joint. The incision is carried down through the skin and subcutaneous tissues to expose the cruciate ligament overlying the joint. This ligament is split in the direction of its fibers and the sinus tarsi is dissected free of adipose tissue and ligamentous structures. In some instances, in order to get better exposure, the short toe extensors have been dissected from the calcaneus and reflected forward. With this exposure the relationship of the calcaneus to the astragalus can be readily seen and the mechanism of the deformity can be clearly demonstrated. If the foot is placed down into equinus, the calcaneus can usually be replaced beneath the astragalus by inverting the foot. If the deformity is severe and has been present for a long time, it may be necessary to divide the posterior capsule of the subastragalar joint or remove a slight amount of bone laterally beneath the anterior superior articular surface in order to restore proper alignment. An osteotome or broad periosteal elevator is inserted into the sinus tarsi as a block to demonstrate the stability which might be obtained with the grafts. This also is done to determine the size of the grafts and the optimum position in which they may be placed. In three cases the distal portion of the calcaneus could not be maintained beneath the astragalus, although the eversion was well corrected; in these cases a screw was inserted across the distal astragalo-calcaneal joint from above. The sinus tarsi is prepared for the grafts by the removal of a thin layer of cortical bone from the under surface of the astragalus and the superior aspect of the calcaneus.

A linear incision is then made over the upper portion of the tibia, and the periosteum is incised over the anterior surface of the cortex in the metaphyseal region, in order to provide cancellous as well as cortical bone. A piece of bone large enough to provide two grafts is removed with the saw. This usually is about 3.5 to 4.5 centimeters long and about 1.5 centimeters wide. The grafts are cut to size and are trapezoid in shape. The corners of the broad base are removed with a rongeur, so the grafts will countersink into the cancellous bone and prevent lateral displacement (Fig. 4). The grafts are placed in the sinus tarsi with the foot held in the slightly overcorrected position and then, as the foot is everted, the grafts are locked in the desired position. The tension on the grafts should favor healing. The cancellous portion of the grafts make a favorable surface for bone repair and are placed adjacent to each other. The foot is usually very stable after the insertion of the grafts and, in many instances, the equinus deformity can be corrected at operation. A cast is applied from toe to groin with the knee flexed and the foot in maximum dorsiflexion.

If there is no residual equinus and tendon transplantation is indicated, it is preferable to do this at the same operation. Exercises for the transplant may be started six weeks after operation, and weight-bearing has been allowed when healing of the grafts is observed

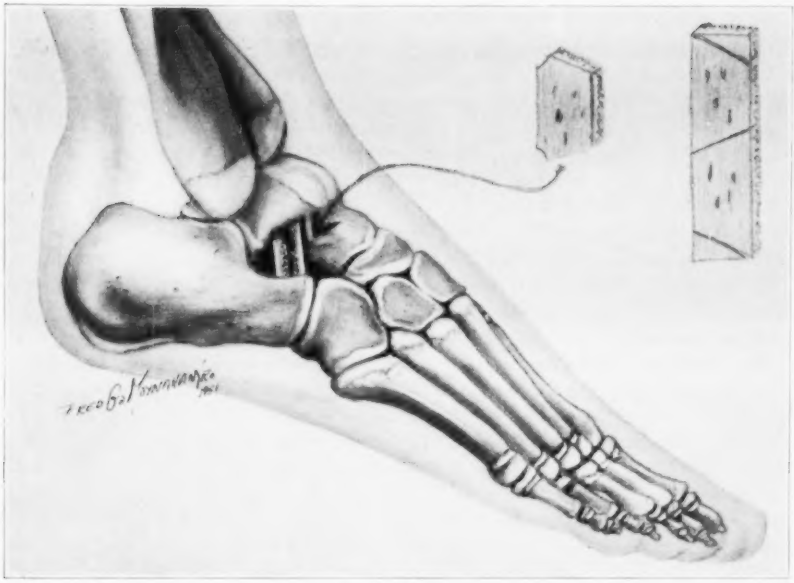

FIG. 4

Placement of grafts in sinus tarsi. Corners of base rongeured away to allow countersinking.

in the roentgenograms. This is usually about ten to twelve weeks after operation. If residual equinus is found at operation, any tendon transplantation is deferred until the foot has been wedged up postoperatively. Occasionally it has been possible to do the tendon transference six to eight weeks after the arthrodesis, but at other times it has been postponed until the foot has been mobilized and the muscles have regained power. If the operation is performed on very young children, it may be advisable to defer any tendon procedures until the child is old enough to be instructed properly in the use of the transplanted tendon. The type of tendon transplantation will be discussed later.

DISCUSSION

This technique of using bone grafts placed in the sinus tarsi to obtain an extra-articular arthrodesis of the subastragalar joint was first used at the Children's Hospital in 1945 at the suggestion of Dr. William T. Green. The result was very favorable and after the patient had been observed for four years without evidence of recurrence, it was decided to do the operation in eight more cases in 1949 and 1950. A preliminary report * on the experience gained in these nine cases was presented at the meeting of The American Orthopaedic Association in 1950. It was stated in that paper: "The results have been quite satisfactory with the exception of one case in which the deformity had recurred." The limited experience with this operation and the observation of one poor result made it seem advisable to postpone publication of this procedure until a more adequate follow-up had been obtained.

This operation has now been performed on twenty-two paralytic flat feet; considerable experience has been obtained in the technical aspects of the procedure and an appreciation has been gained of the limitations of the operation. Although the postoperative follow-up is still rather short, there is sufficient merit in the method to warrant publication

* Read at the Annual Meeting of The American Orthopaedic Association, Virginia Beach, Virginia, May 26, 1950.

of our experiences to date. Of the twenty-two patients, one has now been observed for six years since operation, eleven were operated upon eighteen months to two years ago, five were operated upon over a year ago, and five have been treated too recently to permit evaluation of the end result. Seventeen patients have been followed at least one year, and of these, fifteen have been classified as having a good result and two as having a poor result due to recurrence of the deformity. In all cases, the arthrodesis has been successful, and the grafts have become solidly incorporated into the adjacent bones.

If tendon transplantation has been indicated, it has been done in conjunction with the arthrodesis whenever possible, but in some instances it has had to be deferred because the equinus was not corrected completely. When there is moderate deformity, one of the peroneal muscles has been transferred to the base of the second metatarsal and a good result has been obtained. In the severe deformities, however, it has been necessary to provide support beneath the astragaloscaphoid region in order to prevent recurrence. In seven cases the peroneus longus has been transferred beneath the astragalus and calcaneoscaphoid ligament and attached to the scaphoid through a drill hole. In one instance the flexor hallucis longus was transplanted into the posterior tibial sheath and passed beneath the astragalus and inserted into the scaphoid. The deltoid ligament has also been reattached to correct the relaxation of the medial ligamentous support. This combination of soft-tissue procedures and the arthrodesis has been quite satisfactory in the recent cases. A longer follow-up is needed to ascertain whether the correction will be maintained throughout the growing period, but one patient has been followed for six years with no evidence of recurrence. A brief résumé of his case history will be presented.

The first patient in this series was five years old when the operation was performed. The boy was born in 1940 and had onset of poliomyelitis in 1941. Residual involvement of the left leg was moderately severe. There was complete paralysis of the anterior and posterior tibials, long toe flexors were *fair*, gastrocnemius was *fair plus*, and the other muscles were *good*. A severe valgus deformity of the left foot developed, with marked plantar flexion of the astragalus (Figs. 5-A, 5-B, and 5-C). The astragalus was in so much equinus that the foot was wedged up in plaster casts before operation. In August 1945, a subastragalar arthrodesis was performed, with the use of bone grafts from the diaphysis of the tibia. At the same time the peroneus longus was transplanted beneath the calcaneoscaphoid ligament and inserted into the scaphoid. An excellent result was obtained and correction of the deformity has been maintained (Figs. 5-D, 5-E, and 5-F). The x-rays taken four years postoperatively revealed that the height of the tarsus had been maintained, and growth had occurred (Fig. 5-H).

In this case the grafts were taken too low in the shaft of the tibia and were entirely of cortical bone. They were very slow in becoming incorporated into the adjacent bones and weight-bearing was not permitted until four and a half months after operation. In the subsequent cases, grafts have been removed from the metaphyseal region, providing thinner cortical bone but more cancellous bone, and healing has occurred in ten to twelve weeks.

The next patient is presented to illustrate that the correction of muscle imbalance requires individual consideration.

This boy was born in 1944 and had onset of poliomyelitis in 1945 when he was one year old. His muscle examination in 1950 showed the following ratings: gastrocnemius *fair plus*, anterior tibial *zero*, posterior tibial *zero*, peroneus longus *good*, peroneus brevis *good*, extensor hallucis *good*, extensor digitorum communis *good*, flexor hallucis *good*, flexor digitorum longus *good*. This boy had generalized ligamentous relaxation, and a severely pronated foot developed (Figs. 6-A, 6-B, and 6-C). A lateral x-ray of the foot, with the boy standing, revealed the astragalus to be in moderate plantar flexion (Fig. 6-D). There was considerably more eversion and dorsiflexion of the metatarsus than of the heel; this was associated with a very strong peroneus tertius and extensor digitorum communis. It was proposed, therefore, to perform the subastragalar arthrodesis and then to balance the muscle pull on the metatarsus. Transplantation of the peroneus longus to the astragaloscaphoid region was deferred, with the idea that this could be done later if needed. In April 1950, an arthrodesis of the subastragalar joint was performed. Eight weeks after operation the cast was bivalved, so that the skin could be prepared for tendon transplantation. In July 1950, the peroneus tertius and extensor digiti quinti were transplanted to the second metatarsal and the extensor hallucis longus was transplanted to the neck of the first metatarsal. Eighteen months after operation the foot had a good clinical appearance and excellent function (Figs. 6-F to 6-J).

FIG. 5-A FIG. 5-B FIG. 5-C

Severe deformity of left foot in five-year-old boy.

FIG. 5-D FIG. 5-E FIG. 5-F

Four years after subastragalar arthrodesis and transplantation of peroneus longus to astragaloscaphoid region.

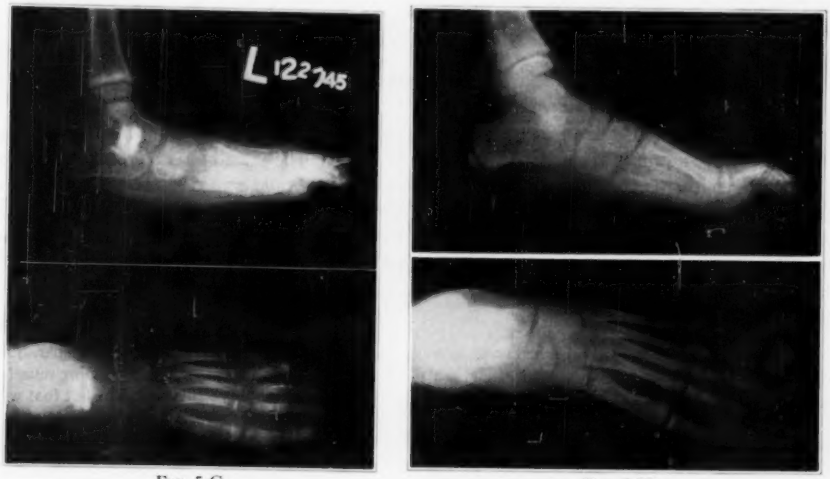

FIG. 5-G FIG. 5-H

Fig. 5-G: X-rays four months after operation, showing dense cortical grafts.

Fig. 5-H: X-rays four years postoperatively. Relationship had been maintained. Growth had occurred in tarsus.

FIG. 6-A FIG. 6-B FIG. 6-C

Severe deformity of right foot in six-year-old boy.

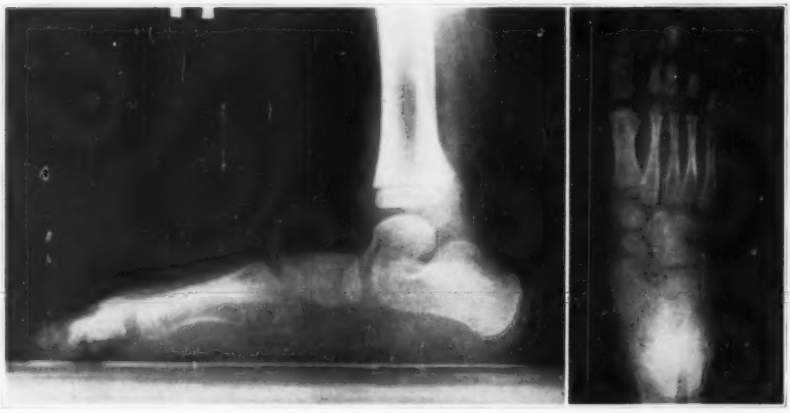

FIG. 6-D FIG. 6-E

Standing lateral and anteroposterior views.

If there should be any evidence of recurrence, the peroneus longus will be transplanted beneath the astragaloscaphoid region.

The poor results occurred in two patients who had such severe deformities that the astragalus was in equinus of almost 90 degrees. The first patient had only a transplantation of the peroneus longus to the second metatarsal, and no support was given to the astragaloscaphoid region. The deformity recurred within six months after operation, and revision of the operation has not been done as yet. The second patient did not have any tendon transference at the time of the arthrodesis and had a complete recurrence of the deformity. A brief résumé of his case will illustrate the necessity of providing support to the medial longitudinal arch.

H. D. was a boy, born in 1944. He had onset of acute poliomyelitis in 1946. There was complete paralysis of the anterior and posterior tibial muscles. The gastrocnemius was rated *fair plus*. The remaining muscles were rated *good* to *normal*. He had generalized relaxation of all his ligamentous structures. The left foot was supported with a plate and a short leg brace with an inner T strap for several years. A night cast was used to keep the foot inverted while at rest. In spite of all this, a severely pronated foot developed (Figs. 7-A and 7-B). The Achilles tendon was very tight. The calcaneus became everted, and the astragalus dropped into marked equinus (Fig. 7-C). In May 1950, a subastragalar arthrodesis with bone grafts was performed. Good alignment of the calcaneus and astragalus was obtained, but the equinus of the foot was not corrected (Fig. 7-D). Because it would have interfered with his return to school, the tendon transplantation was not done and the boy resumed weight-bearing in August, three and one-half months after fusion. He wore a brace and

FIG. 6-F FIG. 6-G FIG. 6-H

Appearance eighteen months after operation.

FIG. 6-I FIG. 6-J

Standing lateral and anteroposterior views. Astragalus in slight plantar flexion. Adduction of metatarsus had been corrected.

a plate in his shoe, but the deformity recurred completely, and a peroneal spasm developed which held the tarsus in marked eversion (Figs. 7-E and 7-F).

It was difficult to reconcile the gross appearance of the flat foot with the x-ray record of solid fusion of the subastragalar joint (Fig. 7-G). The first implication was that the correction had not been maintained and that the joint had fused in deformity, but special views proved that this was not true (Fig. 7-H). The deformity recurred because the entire mass of the astragalus and calcaneus became displaced in respect to the ankle joint. The deltoid, calcaneoscaphoid, and astragalotibial ligaments were stretched as the tarsus was displaced into valgus by the peroneal muscles.

A long cast was applied in April 1951, and the foot was wedged up into dorsiflexion. In May 1951, the deltoid ligament was reconstructed and the peroneus brevis was transplanted beneath the astragalus and inserted into the scaphoid. After operation the foot was brought into more dorsiflexion, and x-rays taken on September 4, 1951 revealed that the equinus had been corrected. This procedure has resulted in correction of the deformity as shown in the photographs taken six months after operation (Figs. 7-I and 7-J).

The question arises whether the correction will be maintained and, therefore, this case is still classified as a poor result in the series.

FIG. 7-A

FIG. 7-B

H. D., six years old. Severe flat foot on the left with heel off floor.

FIG. 7-E

FIG. 7-F

One year after subastragalar arthrodesis, showing complete recurrence.

FIG. 7-C

FIG. 7-D

Fig. 7-C: Standing lateral view, showing astragalus in 90-degree equinus.
Fig. 7-D: Postoperative x-ray. Astragalus had improved but was still in plantar flexion.

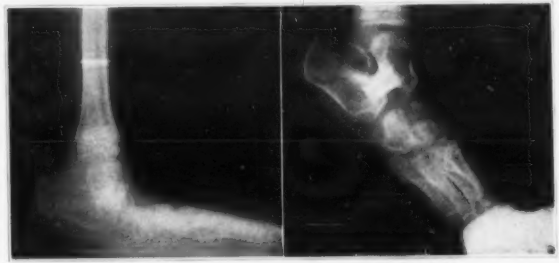

FIG. 7-G

FIG. 7-H

Fig. 7-G: Standing lateral view is almost identical with preoperative x-ray (Fig. 7-C).
Fig. 7-H: Lateral view with foot inverted. Relationship shown in Fig. 7-D has still been maintained.

FIG. 7-I FIG. 7-J

Six months after tendon transplantation and ligament reconstruction.

There have been only two cases in which the deformity was not corrected by this operation, and the problem in these has been described. However, there have been other difficulties encountered in regard to the operative technique. In one of the poor results already described, there was an additional factor contributing to the recurrence other than the muscle imbalance. At the operation the calcaneus was not displaced far enough medially beneath the astragalus and, as a result, the tarsus was mechanically unstable. If difficulty is encountered in maintaining the distal end of the calcaneus beneath the astragalus, this can be alleviated by placing a screw across the distal astragalocalcaneal articulation. This is inserted from above through a separate small incision placed over the head of the astragalus. If the grafts are too small or placed so the superior edges slant distally, the calcaneus will not be solidly fixed beneath the astragalus and correction may not be maintained.

All of the grafts in this series were obtained from the upper third of the tibia of the involved leg. The youngest patients in the series were five years old, and no difficulty was encountered in obtaining grafts of adequate size from the metaphyseal region. In several patients, there appears to have been a stimulation of growth following the removal of the grafts from the tibia. This is an unpredictable but desirable result, since the extremity is usually shorter on the involved side.

Although we have had no personal experience with bank bone for the grafts, we have heard from Dr. Oscar Malvarez of Argentina that he has had excellent results with bank bone in a series of eighteen cases, reported at the Congress of the *Sociedad Latino-Americana de Ortopedia y Traumatología* in December 1950. He uses a graft which is countersunk into slots made in the astragalus and calcaneus. His patients were only two or three years old and no tendon work was done. Fusion has occurred in all of his cases.

It is our opinion that this operation is well adapted to the age group from four to seven years, and it has been successfully accomplished in children of ten and eleven years. If the deformity is severe, it is more difficult to correct in the older age group.

All but two of the patients in this series had complete paralysis of the posterior tibial and usually of the anterior tibial. In most instances the peronei and gastrocnemius were strong muscles. In two cases, however, the deformity occurred following posterior transplants in which the posterior tibial, flexor hallucis longus, and peroneus longus had been transferred to the calcaneus. In both of these the deformity was well corrected by subastragalar arthrodesis, and an excellent weight-bearing foot resulted.

This technique of subastragalar arthrodesis has been used to correct other deformities in young children, such as severely pronated feet, the rocker deformity in club-foot, and the congenital flat foot with plantar-flexed astragalus, with which this paper does not deal. The operation would appear to be deserving of consideration in these conditions.

SUMMARY

Correction of pronated feet by arthrodesis of the subastragalar joint or by procedures adapted to limit eversion at the subastragalar joint has been accomplished by many sur-

geons. In this paper a method of obtaining fusion of the subastragalar joint with bone grafts is presented. The advantage of the method is that height is restored to the tarsus by the operation. Since the grafts are placed in the sinus tarsi, they are essentially extra-articular in position and should interfere with growth in a minimal degree. The technique is simple and mechanical fixation of the joint is obtained with the grafts.

When the deformity is due to paralysis, the muscle imbalance must be corrected to prevent recurrence of the deformity. In cases of mild to moderate severity, it is advisable to transfer the peroneus longus to the base of the second metatarsal. The severe cases in which the astragalus is in marked equinus require tendon transference which provides support to the astragaloscaphoid region.

Although this operation has been used primarily in the correction of paralytic flat feet, it would seem to be of merit in the treatment of severely pronated feet in young children and the rocker deformities of club-foot.

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DISCUSSION

Dr. J. H. Kite, Atlanta, Georgia: Dr. Grice recommends for children with paralytic flat feet that a subtalar arthrodesis be done early, in order to prevent gross deformity of the feet. At this early age there is more cartilage and less bone in the joints; so a bone graft is used to ensure fusion. This fusion is done at only one point in the subtalar joint, the tarsal sinus.

The subtalar joint which is being fused is not in a flail foot in which there is little or no strain on the fusion, but it is in a paralytic foot with paralysis of the tibials and with strong peronei and gastrocnemius. We have found that a triple arthrodesis is not able to hold the foot straight against a gross muscle imbalance in a young child; so I question if the fusion of a part of one joint will hold the correction.

The accepted procedure in the past, when the child is too young for a stabilization, has been to transfer the muscle at an early age. This will lessen the deformity and in some cases will prevent deformity. The muscle transference may be all that is necessary, even though it does not give a complete stabilization. If the muscle balance is not as good as desired, a minimum amount of support can be used until the child is old enough for stabilization.

Dr. Grice says that, if he waits until the usual time for stabilization which is from eight to ten years the deformity will become so severe that considerable bone will have to be removed and that considerable height of the foot will have to be sacrificed or one must accept a foot which is displaced lateralward in respect to the joint.

I doubt if these objections are valid. A flat-foot type of stabilization can be done at the usual time with very little loss of height. No matter how severe the flat-foot deformity may be, it can always be completely corrected by a properly executed stabilization.

The younger the child, the greater the chance for a recurrence of the deformity, especially when there is muscle imbalance. It is the young child who needs the strongest fusion. I am afraid that fixation of only one point in the tarsal sinus is not enough to keep the foot from gradually relapsing into a flat foot.

In 1913, Davis of Philadelphia described a method of "horizontal transverse section" of the foot with

(*Continued on page 955*)

CONGENITAL ABSENCE OF THE FIBULA*

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The fibula, of all the long bones, is the one most commonly congenitally absent; congenital absence of the tibia, the ulna, the radius, and the femur follow in order of frequency.[9] Congenital absence of the fibula was first described, as far as we can determine, by Göller in 1698 and cited by Meckel in 1812.[7] Numerous reports of this condition have since appeared in the medical literature. It is not the purpose of this paper to review all of these reports, but rather to present the findings in twenty-nine cases of congenital absence of the fibula observed at the Mayo Clinic from 1913 through 1947. The diagnosis was verified by roentgenographic examination.

The classical syndrome is one of complete or almost complete absence of the fibula, anterior bowing of the distal third of the tibia with a dimple in the skin at the point of greatest angulation, marked talipes equinovalgus, absence of one or more rays of the foot, and absence of one or more, or fusion of two or more, tarsal bones. This picture is frequently modified, and included in our series are cases in which the defect consists only of an absence of the proximal fibular epiphysis, and others in which it consists of severe bilateral deformity with congenital changes in other parts of the body.

ORIGIN

Two theories of origin are acceptable in the light of present knowledge of embryology. Bardeen and Lewis in 1901 concluded from an exhaustive study that defects must occur in the embryo by the sixth or seventh week of life in order to produce the absences of bone seen in this syndrome. The cause of these defects in the germ plasm is unknown, and nothing in our study sheds any light on the problem. A second theory of origin was postulated by Middleton in 1934. He concluded that the absence of the fibula may be a secondary defect. The primary defect he assumed to be failure of maturation, the last stage of which is growth in length of muscle fiber. This failure of longitudinal growth produces a relative shortening of the calf and peroneal muscles, which in turn places abnormal stress on the tibia and foot, causing bowing and equinovalgus. The two theories are not incompatible, and it is possible that a combination of the two processes produces this defect.

HEREDITY

Heredity appears to play a minor role in congenital absence of the fibula. No familial instances of absence of fibula were found in our cases.

Pregnancy and birth were normal in most of our twenty-nine cases. None of the patients' mothers had had German measles (rubella) during pregnancy as far as could be determined. It is interesting that one patient was one of twin boys; the other twin was normal.

CLASSIFICATION

In order to determine the best general plan of treatment, as well as to determine the prognosis when this treatment is to be employed, the syndrome of congenital absence of the fibula in our series has been divided into three main types.

* Based on an exhibit at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27 to February 1, 1951.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Congenital absence of the fibula, Type I, shown in anteroposterior views of both lower extremities in a girl five years old. The left lower extremity shows shortening of one and one-half inches (3.8 centimeters) and absence of the proximal third of the fibula.

Fig. 1-B: Lateral view of the left lower extremity.

Type I

In this type the patients have partial, unilateral absence of the fibula with little or no bowing of the tibia (Figs. 1-A and 1-B). The extremity is always shortened. There is little or no deformity of the foot. There are no other obvious congenital anomalies in other parts of the body. This type of absence of the fibula frequently escapes diagnosis because of the minimal changes. It may be revealed unexpectedly during roentgenographic examination. Shortening is the most common sign. The degree of absence of the fibula may range from absence of the proximal fibular epiphysis to almost complete absence of the fibula. Little disability is present, and the only treatment required is a heel lift on the affected side or epiphyseal arrest on the normal side.

In our series of twenty-nine cases we encountered three cases of Type I absence of the fibula (10.3 per cent.).

Type II

In cases of this type the fibula is completely or almost completely absent. The involvement is unilateral. The classical deformity is present, with anterior bowing of the tibia, dimpling of the skin, equinovalgus of the foot, and absence or deformity of the rays and tarsal bones. There is always marked shortening of the extremity (Figs. 2-A and 2-B).

Patients who have this type of condition invariably need treatment. The prognosis for function and appearance is relatively poor. Methods of treatment will be discussed later. This type of deformity occurred in ten of our twenty-nine cases (34.5 per cent.).

FIG. 2-A

FIG. 2-B

Fig. 2-A: Congenital absence of the fibula, Type II, in a boy one month old. The right leg shows a dimple over the lower third of the tibia, anterolateral bowing of the tibia, calcaneovalgus of the foot, and absence of two rays.

Fig. 2-B: Anteroposterior view of both lower limbs in the same patient.

Type III

Included as Type III deformity are cases of (1) congenital absence of the fibula of Type I or Type II associated with other congenital deformities (Figs. 3-A to 3-E), and (2) bilateral absence of the fibula (Figs. 4-A to 4-C). In Type III the congenital absence of the fibula, therefore, must be accompanied by other congenital defects or it must be bilateral. The condition in most of these cases is difficult to correct, and the prognosis for adequate function is poorer than in patients with Type I or Type II deformity.

This is the largest group. Type III deformity occurred in sixteen of our twenty-nine cases (55.2 per cent.).

ASSOCIATED CONGENITAL ANOMALIES

Associated congenital anomalies in other parts of the body occurred in ten of the sixteen cases of Type III absence of the fibula. This is 34.5 per cent. of the entire group. The anomalies were in the upper extremities in four cases (Figs. 5-A and 5-B). In one case a unilateral fibular defect was associated with absence of one ray in the opposite foot. In three cases the femur was the site of an associated anomaly. Spina bifida was associated with unilateral defect of the fibula in two cases.

In our series, with few exceptions, the femur on the side of the defect was somewhat shorter, and the development of the capital femoral epiphysis and acetabulum was delayed. We did not include these changes as an associated congenital anomaly, as they occur in most cases of congenital absence of the fibula.

FIG. 3-A

FIG. 3-B

FIG. 3-C

FIG. 3-D

FIG. 3-E

Figs. 3-A and 3-B: Front and side views of both limbs show congenital absence of the fibula, Type III, in a boy nine years old. Shortening of the extremity, equinovalgus deformity of the foot, and the dimple (under the operative scar) may be noted.

Figs. 3-C and 3-D: Anteroposterior and lateral views of the right leg.

Fig. 3-E: Anteroposterior view of acetabula and femora, showing congenital shortening of the right femur with pseudarthrosis of the femoral neck.

FIG. 4-A

FIG. 4-B

Figs. 4-A, 4-B, and 4-C: Photograph and anteroposterior and lateral roentgenograms of the lower limbs of a girl two weeks old; this is a good example of a Type III bilateral absence of the fibula.

INCIDENCE

The defect of the fibula was on the right side alone in seventeen of our cases, on the left alone in five, and on both sides in seven. Nineteen of our patients were females and ten were males. These figures correspond to those reported by most authors in the literature. Corner, however, found that the anomaly "evinces a slight tendency to occur more frequently in males" than in females. Our study shows an almost two to one predominance in females. Lapasset and Cahuzac found that some authors reported a higher incidence in girls, while others observed the incidence to be higher among boys. Corner found the right side affected more often than the left, as did we.

DIFFERENTIAL DIAGNOSIS

Congenital Absence of the Tibia

In reviewing our cases for this study, we found two cases in which congenital absence of the tibia had been diagnosed as congenital absence of the fibula. This is understandable, for the differential diagnosis is sometimes most difficult to make. In gross appearance there are three important points of difference: (1) The foot and ankle in congenital absence of the tibia are in a varus position, not in valgus. The medial malleolus

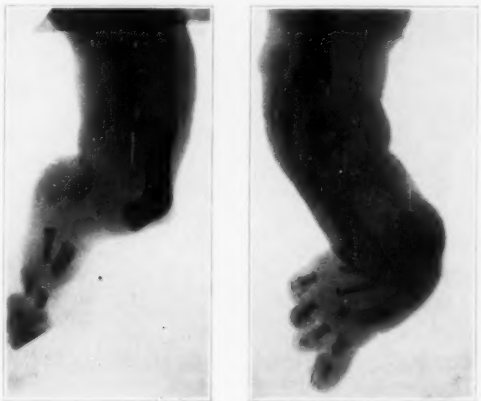

FIG. 4-C

FIG. 5-A FIG. 5-B

The hands of a patient who had congenital absence of the fibula, Type III, demonstrating congenital lesions of the upper extremity.

is missing, with resulting medial displacement of the ankle. (2) While atrophy and shortening of the leg are present, as in congenital absence of the fibula, there is little or no anterior bowing of the leg. (3) There is dislocation at the knee. Without the normal articulation of the tibia on the femur, the fibula rides laterally and there is no true knee joint (Figs. 6-A and 6-B).

Roentgenographically it is occasionally difficult to distinguish between the tibia and

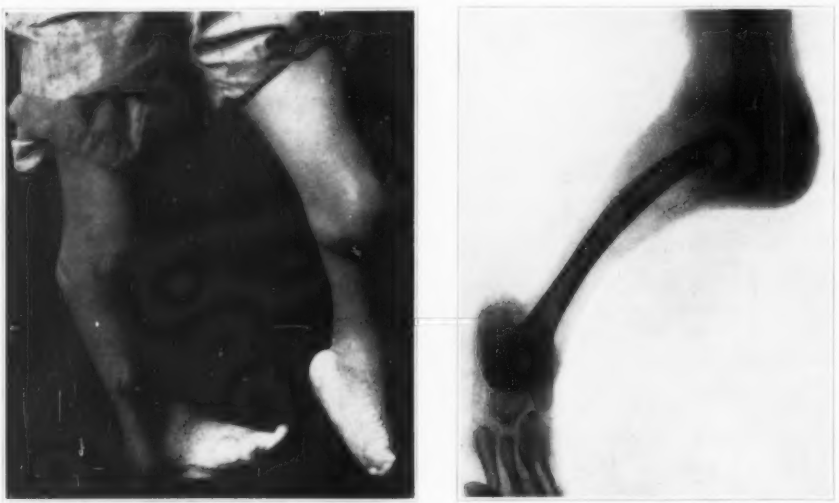

FIG. 6-A FIG. 6-B

Fig. 6-A: Congenital absence of the tibia. There is also subluxation of the left knee, bilateral talipes equinovarus, bilateral dimpling of the lower third of the legs, and deformity of the toes of both feet.

Fig. 6-B: Anteroposterior views of the left leg showing marked hypertrophy of the fibula and absence of the tibia.

Fig. 7: One type of prosthesis which may be applied to compensate for shortening and deformity.

fibula. The type of deformity of the foot, as mentioned previously, is of aid, and the fact that the upper end of the fibula is not broadened and does not actually articulate with the femur helps to distinguish it as a fibula. The bowing, if any, is more lateral than anterior when the tibia is missing. Our experience has shown that amputation is the best procedure when the tibia is absent; this is not usually the case when the fibula is absent. The differential diagnosis is therefore extremely important.

Congenital Pseudarthrosis of the Tibia

The gross appearance of the leg in cases of congenital pseudarthrosis of the tibia is often similar to that in cases of congenital absence of the fibula. A dimple is often present at the maximal angle of bowing. The bowing is near the juncture of the middle and lower thirds of the leg, as in absence of the fibula. Perhaps the most distinctive differential point on examination is the absence of a relatively fixed equinovalgus. Other congenital anomalies are infrequent in association with congenital pseudarthrosis, but common in association with congenital absence of the fibula, as we have pointed out. If actual fracture has occurred, the diagnosis is more apparent.

FIG. 7

Williams gave a clear idea of the differential diagnosis by roentgenograms. In congenital pseudarthrosis the tibia and fibula are thickened and may be angulated or fractured. The fibula is always present except at the site of the pseudarthrosis. In congenital absence of the fibula, which he preferred to call "congenital angulation of the tibia", the fibula, or a part of it, is absent and the tibia is not markedly thickened or sclerotic.

Congenital absence of the fibula must be distinguished from congenital pseudarthrosis. Osteotomy for congenital absence of the fibula is not dangerous; union oc-

FIG. 8-A

FIG. 8-B

FIG. 8-C

Fig. 8-A: The side view shows the deformity in a typical case of congenital absence of the fibula.
Fig. 8-B: Showing the type of prosthesis worn by the same patient.
Fig. 8-C: Front view of the patient, showing the same prosthesis and deformity.

FIG. 9-A

FIG. 9-B

Fig. 9-A: Congenital absence of fibula, Type II.
Fig. 9-B: Anteroposterior and lateral views of the right leg.

curs promptly, as we will point out. This is, of course, not the case in congenital pseudarthrosis.

Shortening of the Lower Extremity without Absence of the Fibula

A variety of conditions may cause disturbance of growth of the lower extremity, and the gross changes may simulate those in the milder cases of congenital absence of the fibula.

Congenital Equinovalgus

This is rarely seen alone without changes in bone. It is due to the same causes as other types of club-foot. The condition may be confusing on inspection, but a roentgenogram will show the fibula.

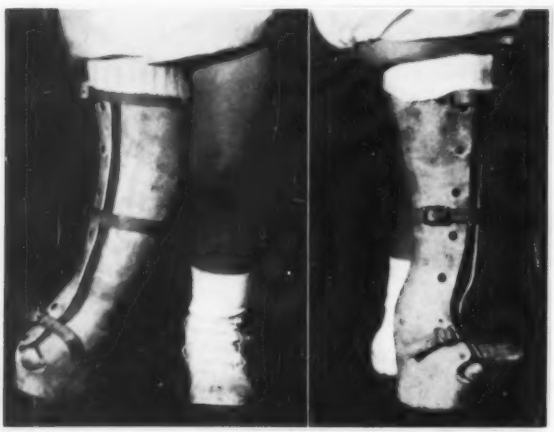

FIG. 9-C
Front and side views of the celastic prosthesis used in this case.

Posteromedial Bowing of the Tibia and Fibula

As reported by Heyman and Herndon, the bowing is posterior and medial, and the deformity of the foot is the calcaneus, not the equinus, type. The roentgenogram will show the presence of an entire fibula.

TREATMENT

The syndrome of congenital absence of the fibula shows definite development

FIG. 10-A

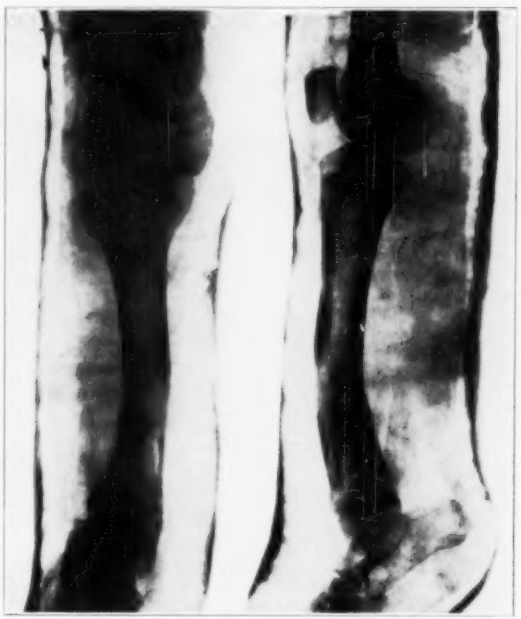

FIG. 10-B

Fig. 10-A: June 19, 1941. Lateral view of the right lower extremity, showing congenital absence of the fibula.

Fig. 10-B: June 23, 1941. Anteroposterior and lateral roentgenograms made after lengthening of tendo achillis and osteotomy of the tibia on the right. The incised bone was held in place with a cast. When the patient was last heard from, in 1947, he was able to dance and ride a bicycle.

and progression as growth occurs and the child develops into an adult. The lack of normal function causes abnormal development, according to Wolff's law. We have studied these patients to determine the treatment recommended, the treatment ultimately received in our hands and in the hands of others, and the results of such treatment as of January 1, 1951. By observing these patients we have been able to formulate certain basic criteria for treatment, but we would like to caution against oversimplification and generalization in this regard. Each case is different to a greater or lesser degree.

The basic principle of treatment is active exercise and weight-bearing. The ultimate objective is adequate function. Means must be found to achieve this objective. Only by weight-bearing will the bones and muscles be strengthened and the epiphyses develop properly. As in other musculoskeletal conditions, we have found nothing to take the place of active motion. Massage and stretching are of little value. To allow weight-bearing in as normal a manner as possible we use both prosthetic devices and surgical procedures.

Prostheses

The prosthesis most frequently used in the past consisted of a high-laced shoe built up inside and outside (Fig. 7), a pylon, or a type of brace with a "false shoe" and a thigh cuff (Figs. 8-A to 8-C). Recently we have been using a prosthesis made from a material called "celastic". This is made over a plaster mold. It has the advantage of careful fitting, lightness, and semipermanency, and can be readily changed as the child develops. It is fitted as soon as weight-bearing begins, after plaster casts and attempted correction of the deformity (Figs. 9-A to 9-C). It is continued until a special shoe is substituted. Further development of plastics may improve this type of prosthesis and make it available to older children.

FIG. 11-A

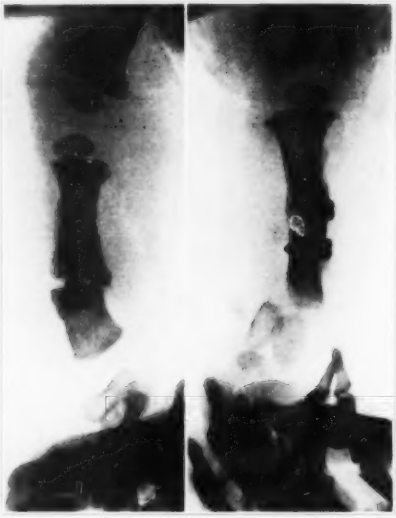

FIG. 11-B

Fig. 11-A: November 23, 1938. Lateral and anteroposterior roentgenograms, showing a typical deformity in a case of congenital absence of the fibula. (Courtesy of Dr. G. H. Ryan, Winnipeg, Manitoba, Canada.)

Fig. 11-B: May 15, 1939. The same deformity following osteotomy and internal fixation. (Courtesy of Dr. G. H. Ryan, Winnipeg, Manitoba, Canada.)

FIG. 11-C FIG. 11-D

June 19, 1944. Lateral and anteroposterior roentgenograms five years later, after astragalectomy. (Courtesy of Dr. G. H. Ryan, Winnipeg, Manitoba, Canada.)

Surgical Procedures

Surgical procedures which we employ may be classified as follows: (1) casts; (2) operations on soft tissue; (3) bone-cutting procedures, such as tibial osteotomy, tarsal arthrodesis, and malleolar graft; (4) epiphyseal arrest; and (5) amputation.

Harmon and Fahey emphasized that the two main problems in surgical correction are the deformity of the foot and the angulated and shortened tibia. The deformity of the foot is an equinovalgus, with absence of the lateral malleolus and of some of the rays and tarsal bones. This is accompanied by shortening of the calf muscles. It can be partly corrected by application of wedged casts. Treatment should be started as soon after birth as possible. The foot can be brought under the tibia by this means, but not all of the equinus can be corrected. Further correction can be obtained by operations on the soft tissues, including lengthening of the tendo achillis, posterior and lateral capsulotomy, and section of the peroneal tendons. The corrected extremity is then held in a prosthetic device which permits weight-bearing. This is essentially the treatment described by Ashhurst in 1916; he followed it

FIG. 12-A

FIG. 12-B

FIG. 12-C

FIG. 12-D

FIG. 12-E

Fig. 12-A: Case 1. Anteroposterior view of proximal third of both legs.

Fig. 12-B: August 11, 1949. Lateral view of distal part of the right leg, foot, and ankle.

Fig. 12-C: August 11, 1949. Anteroposterior view of both feet.

Fig. 12-D: Lateral view of left leg, ankle, and foot.

Fig. 12-E: July 25, 1950. Appearance of left tarsus after lengthening of the tendo achillis, posterior capsulotomy, and cuneiform osteotomy and arthrodesis of the tarsal bones.

with a tibial graft to replace the lateral malleolus. Bone-grafting was used in one of our cases (Figs. 12-F and 12-G). During any surgical treatment the epiphyseal plates must not be disturbed. When the child has matured to the age of ten to twelve years, tarsal arthrodesis may be carried out in conjunction with cuneiform osteotomy to correct some of the deformity. The indication for this depends on the extent of the deformity, both in the soft tissue and in the bones.

The second problem, that of the deformity of the tibia, divides itself into the problems of bowing and of shortening. Osteotomy will help to correct the marked equinus due to growth deformity (Figs. 10-A and 10-B, 11-A to 11-D, 12-A to 12-G). Before the osteotomy, the tight posterior and lateral structures should be lengthened or cut. Otherwise correction cannot be obtained. We have performed four tibial osteotomies and one has been performed in one of our cases elsewhere*. In all of these cases, healing has occurred without delay or complication. The fear of non-union seems groundless in view of this experience. The condition is in no way comparable to that of congenital pseudarthrosis. There is no basic pathological defect, such as neurofibroma or hamartoma, at the site of the osteotomy. The bowing is a result of external forces and the tibial bone is of normal composition.

FIG. 12-F FIG. 12-G

July 25, 1950. Lateral and anteroposterior views of right leg following osteotomy of tibia and graft of lateral malleolus.

As the technique of epiphyseal arrest is becoming more widely used, its application to the shortening which accompanies absence of the fibula should be considered. The amount of shortening in the patients with Type II deformity is usually marked and epiphyseal arrest must not be performed on the normal side unless most of the inequality can be corrected. Operation

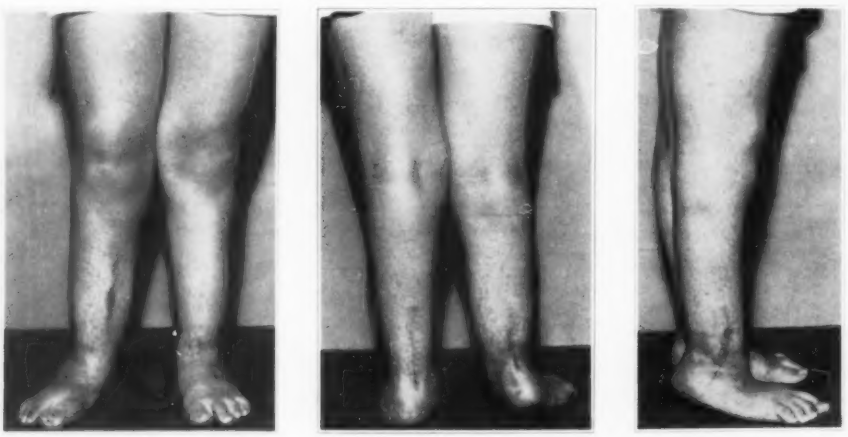

FIG. 12-H FIG. 12-I FIG. 12-J

July 25, 1950. Appearance of legs and feet after surgical correction. Anterior, posterior, and lateral views.

* By Dr. G. H. Ryan, Winnipeg, Manitoba, Canada.

with its resultant shortening in total height is not justified if the patient must still wear a prosthesis. Epiphyseal arrest is probably best saved for patients with Type I deformity. Stimulation of growth on the involved side would be the preferable procedure, but the technique for this has not yet been thoroughly and predictably worked out.

Amputation is a procedure to be considered for patients in the older age group, but not for the infant. It should be carried out only if the child cannot walk with a prosthesis, or if the patient reaching maturity wants an amputation for better function or for cosmetic reasons. Amputation is seldom, if ever, indicated when both fibulae are absent. The two legs in such cases are usually fairly equal in length (Figs. 12-H to 12-J).

In our group of twenty-three traced cases, two amputations have been carried out on female patients. In one case a Gritti-Stokes amputation was performed; in the other the amputation was through the proximal third of the leg. It is probable that more amputations will be done as the younger children reach maturity. The knees in these patients are usually normal, as are the thighs, so that amputation below the knee is usually indicated.

Some of the principles of treatment are illustrated by the following case.

CASE 1. At the age of three and one-half years, the boy was brought to the Clinic by his parents for an opinion concerning multiple congenital deformities. The pregnancy and delivery had been normal.

Examination on admission revealed complete absence of the right fibula with anterior bowing of the tibia and equinovalgus of the ankle and foot. Associated with this was an absence of one ray of the foot (Figs. 12-A, 12-B, and 12-C). In the left lower extremity there was partial absence of the fibula (Fig. 12-A), slight anterior bowing of the tibia and an equinovarus deformity of the foot. One of the metatarsal bones was absent (Figs. 12-C and 12-D). The boy at that time was walking with the aid of a brace on the right foot and a corrective shoe on the left foot.

Plastic procedures on the soft tissues were recommended, but the parents elected to wait. Casts were used at home until the patient was six years old. He wore a brace on the right lower extremity after this.

The child was seen again at the Clinic in August 1949, when he was thirteen years old. The same deformities were present. A program of treatment was outlined and carried out as follows: The left tendo achillis was lengthened, a posterior capsulotomy of the left ankle was performed, and cuneiform osteotomy and arthrodesis of the tarsal bones were carried out (Fig. 12-E). Later the right tendo achillis was lengthened and posterior capsulotomy was done. Much lateral stripping was required and the peroneal tendons were cut. The foot was then brought into varus. The talipes equinus could not be corrected entirely. After these wounds had healed, osteotomy was performed to straighten the right tibia which was held in position with a stainless-steel screw. Three months later a piece of frozen bone-bank ilium was shaped and fixed to the tibia to replace the absent lateral malleolus. The surface of this bone, opposing the talus, was covered with fibrous tissue. The bone was held with one screw, and the graft united. The patient was fitted with shoes and when last examined he was walking with very little limp and without the aid of crutches (Figs. 12-H to 12-J). He plays baseball and basketball.

FOLLOW-UP DATA

Twenty-three of our twenty-nine patients have been followed by direct examination or by letter. If the follow-up data were supplied by letter, photographs were enclosed. Six of these patients have grown to adulthood. Brief histories of these cases follow:

CASE 2. The patient, now a man forty-four years old, had bilateral deformity of Type III. No treatment was given. He now works daily as an electrician, but is having severe pain in both feet (Fig. 7).

CASE 3. A man, twenty-six years old, had deformity of Type II, for which osteotomy of the tibia was performed when he was two months old. He now walks with built-up shoes. He works as a theater manager and states that he has no pain.

CASE 4. This patient, now a woman twenty-one years old, had a typical deformity of Type III, due to congenital absence of the left fibula, together with spina bifida. Sensory and motor loss were noted bilaterally. The left leg had been amputated at the knee when she was a child. At present she wears a brace on the right leg because of weak muscles, and a prosthesis on the left.

CASE 5. The patient, a woman twenty-three years old, had a Type II deformity. She wore a brace until amputation at the age of nine years. She is now married and is very active physically; she stated that she swims, dances, and plays tennis.

CASE 6. A man, now twenty-seven years old, had bilaterial deformities of Type III. Bilateral osteotomy of the tarsus and lengthening of the tendo achillis were performed. He now walks with built-up shoes and conducts a radio business. He has no pain.

CASE 7. A married woman, fifty-two years old, had had bilaterial deformity of Type III. Casts were applied and tenotomies were performed when she was a child. She is a college graduate and a bookkeeper by occupation. She now leads a normal life. Her shoe size is $2\frac{1}{2}$ C.

Four of our patients were between the ages of twelve and twenty-one years at the time of review. Many of the patients have had operations and now are active physically. One patient, a boy, walks with a wooden pylon prosthesis. Another, the boy described in Case 1, wears no brace or prosthesis (Figs. 12-H and 12-I); he had bilateral involvement for which corrective osteotomies were carried out. A third patient, a girl, used only a raised shoe; she stated that she dances, rides a bicycle, does anything she wishes, and is at present a university student. The fourth patient, a boy, walks with a brace and apparently has no pain.

Twelve of our twenty-three patients on whom follow-up data are available are still under treatment and are less than twelve years of age. One died at the age of two years of tuberculous meningitis. This is the only known death in the group. The remaining six patients have not been traced.

COMMENT

Congenital absence of the fibula has been encountered in twenty-nine cases at the Mayo Clinic from 1913 through 1947. We have classified the anomalies in these cases, chiefly for purposes of treatment, into three types. Type I is characterized by partial unilateral absence of the fibula with minimal gross deformity except for shortening. Type II is the classical form, with absence of all or most of the fibula, anterior bowing of the tibia, and equinovalgus of the foot. Type III consists of congenital absence of one fibula, associated with one or more congenital deformities elsewhere, or of bilateral congenital absence of the fibula.

Any deformity including shortening of the lower extremity, bowing of the tibia, equinovalgus of the foot and ankle, or absence of metatarsal bones should be suspected of being part of the syndrome of congenital absence of the fibula until the differential diagnosis has been made. It is of particular importance to distinguish congenital absence of the fibula from congenital absence of the tibia and congenital pseudarthrosis of the tibia. Amputation in infancy is not indicated in congenital absence of the fibula, but may be indicated in congenital absence of the tibia. Osteotomy should not be employed to correct the bowing due to congenital pseudarthrosis of the tibia unless the surgeon is fully cognizant of all the possibilities and can apply massive bone grafts. It can, however, be employed without fear of non-union in congenital absence of the fibula.

Treatment of the deformity due to congenital absence of the fibula should be started as soon after birth as possible. Partial correction by a series of casts is the first procedure. This correction is held until walking age, when a prosthesis can be made. The child walks in this until the age of two or three years, at which time operative procedures can be performed, including posterior and lateral section of soft tissues and osteotomy of the tibia. A prosthesis is then worn until bone growth is completed. Thereafter the lateral malleolus can be grafted if necessary to help hold the calcaneus and talus in position.

Osteotomy of the tibia heals as readily as it would in normal persons, judging from the five cases of congenital absence of the fibula in which we have employed it or have observed the results. Contrary to what seems to be accepted opinion, the bone is of normal structure and does not fail to heal, as does the bone in congenital pseudarthrosis.

Many patients get good functional results from this form of treatment. Amputation

should not be performed in cases of bilateral absence of the fibula. In cases of unilateral absence, it usually should not be done until maturity has been reached; if at that time amputation is indicated for functional and cosmetic reasons, it may be performed. It was found necessary in only two of the twenty-three patients in our series who have been followed.

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DISCUSSION

An Extra-Articular Arthrodesis of the Subastragalar Joint for Correction of Paralytic Flat Feet in Children

(*Continued from page 940*)

backward displacement. Hoke in 1921 combined subtalar arthrodesis and re-implantation of the head and neck of the talus with fusion of the talonavicular joint and posterior displacement of the foot. Later he fused the calcaneocuboid joint also. In 1923 Ryerson described his technique for "triple arthrodesis". This was a rational procedure, since the lateral movements of the foot are functions of the subtalar and talonavicular joints. Fusion of the calcaneocuboid joint affords greater stability and less tendency to recurrence of the deformity. The triple arthrodesis allows a better correction of the deformity.

Dr. J. Albert Key, St. Louis, Missouri: This is similar to the Gallie procedure, but the graft is placed transversely rather than in the longitudinal direction. Dr. Gallie's operation is a good operation—at least it has worked in my hands, and that is a pretty good test. This is also similar to the procedure on which those of us who were in Baltimore heard an adverse report, except that theirs was a bone block and this is an arthrodesis. I see no reason why this shouldn't work from the standpoint of an arthrodesis, provided that autogenous bone is used. I don't think it would be successful in all cases with bank bone, which some of us might be tempted to use. I do feel that the foot should be balanced, because I think that, if a child goes very long with marked muscle imbalance, a deformity will develop. I believe that this will prove to be a very nice and simple method of arthrodesing the subastragalar joint.

Dr. H. R. McCarroll, St. Louis, Missouri: There are two points I wish to stress: First of all, Dr. Grice did point out that muscle imbalance must be corrected; this is one of the features stressed in his presentation. But those of you who have attempted tendon transplantation in young children prior to the age of stabilization know it is no simple task. It requires a magician to transplant these tendons in an unstabilized foot in a young child and obtain balanced function. The second point is that this valgus foot is the most difficult type to stabilize. As Dr. Grice pointed out, the usual stabilization often results in a foot of

(*Continued on page 956*)

(*Continued from page 955*)

decreased height, which is not satisfactory in appearance. One virtue of his procedure is the maintenance of the normal height of the foot which cosmetically will be far more satisfactory.

The procedure he has described is not comparable to the Gallie type of arthrodesis, since the articular surfaces are preserved and the normal growth factor in the foot is not disturbed. I have never used this procedure, but it appears to be based on sound principles and it appeals to me. Very few of our reconstructive measures afford perfect results in all instances. It would seem reasonable to attempt a relatively simple procedure of this type in children of a younger age group since, in the event of failure, a triple arthrodesis can still be performed at a later date.

DR. LEO MAYER, NEW YORK, N. Y.: I have enjoyed hearing this paper very much. It brings out an important factor in correction of severe valgus feet, but I would like to emphasize the importance of restoration of muscle balance. If you do not restore muscle balance, that deltoid ligament is bound to give. There is a tremendous amount of play in the upper part of the ankle joint of the paralyzed foot, far more than we realize in the normal foot, and the only way in which we logically can hope to prevent return of deformity is by restoration of muscle balance. I would stress the importance of transplanting the peroneus longus so as to restore power of inversion. This transplant can best be done by the physiological method so that you may retain the normal gliding action of the tendon. In my experience, it is possible to transplant the peroneus longus successfully in a child of five to six years, and gain restoration of muscle balance. In instances like this, the foot will not be perfect but, following this operation, the use of a light arch support and suitable exercises will secure functional results. Occasionally, in some of these patients at the age of twelve or thirteen, a subsequent stabilization operation is necessary.

DR. GRICE (closing): This may be an uncommon condition, but I do not believe it is rare. At the Children's Hospital Clinic for Poliomyelitis there are 1,800 individual cases under active care each year, and these feet do occur frequently enough to present a constant problem. We have not allowed these feet to be neglected. These children have been followed since the onset of the disease and have often been followed since one year of age. We have used many types of supportive apparatus, including bivalved casts at night to hold the feet in a position of inversion at the heel and maximum dorsiflexion. We have attempted transplantation of the peroneus longus and other soft-tissue procedures at an early age; but I would like to point out that, at the age of six years, the peroneus longus transplant forward is a difficult transplant for the child to learn to use correctly. Reconstruction of the medial longitudinal ligament, correction of the equinus deformity of the astragalus, and transplantation of the peroneus longus beneath the astragaloscaphoid joint have not prevented the recurrence of the deformity. We have patients in whom this deformity has recurred after this operation.

The plantar-flexed astragalus is difficult to prevent from recurring with soft-tissue procedures and, when it has persisted for five or six years, the architecture of the foot is markedly distorted and difficult to correct. The question is asked whether this procedure will be adequate.

We did our first operation on a child barely five years of age. We wanted to do it before too much distortion of the astragalocalcaneal joint had occurred. We were very much concerned with the problem of growth. We felt that, if we could hold the os calcis beneath the astragalus by a bony fusion which would not interfere with growth, the deformity should remain corrected. Growth is equal beneath the astragalus, just as much on the lateral aspect as the medial aspect. Our first patient, who was operated upon at the age of five years, was followed for four years before we attempted other cases. The patient, who is now seven years postoperative, has shown no recurrence of the deformity. By doing this procedure at five years of age or even at four, you not only restore the height of the foot to prevent further deformity from occurring, but you prevent a great deal of functional disability over a long period of time. Even if the procedure should not produce an excellent result, it would not cause any distortion of the foot and it would make a better foot on which to do a triple arthrodesis when the child has completed his growth.

RECURRENT DISLOCATION OF THE PATELLA *

BY IAN MACNAB, F.R.C.S., TORONTO, CANADA

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The problem of recurrent dislocation of the patella has held the interest of orthopaedic surgeons for many years and several corrective operations for this condition have been described. Blumensaat in an extensive review of the literature was able to find reports of seventy-nine different operative techniques. When there are many operations for one condition, this generally means that the results are poor, but from a perusal of the literature it would seem that, irrespective of the type of operative procedure adopted, the surgeon can be reasonably confident that the likelihood of recurrence is not very great.

In the series reported, however, the follow-up periods for the most part have been

TABLE I

CRITERIA FOR JUDGING OBJECTIVE FUNCTIONAL RESULT (F.O.)

Excellent	No abnormal findings.
Good	Wasting quadriceps; flexion of more than 90 degrees, but not full; inability to support body weight on bended knee; pain in the patella.
Fair	Extension limited at not more than 20 degrees; flexion of more than 60, but less than 90 degrees; abnormal movement of patella; clinical symptoms of osteo-arthritis; instability.
Poor	Patella dislocates.

TABLE II

CRITERIA FOR JUDGING SUBJECTIVE FUNCTIONAL RESULT (F.S.)

Excellent	No difficulty at any time.
Good	Occasional slight difficulty.
Fair	Continual difficulty and instability.
Poor	Recurrent dislocation.

short and there has been but perfunctory reference to the degenerative changes which occur in the knee joint. It was felt that a study of the short-term and long-term results, combined with a study of the natural history of the condition, might help to determine the surgical approach to the problem and might assist the surgeon in his choice of technique for a given case.

RESULTS

Sixty-four recurrent dislocations occurring in forty-six patients were reviewed and, in addition, ten cases of congenital dislocation of the patella were studied, so that information on the results of operations performed on children might be obtained.

Of the forty-six patients with recurrent dislocation of the patella, six were males and forty females; the condition was bilateral in eighteen and unilateral in twenty-eight; the average age at the time of the first dislocation in both males and females was thirteen

* Read at the Annual Meeting of The American Orthopaedic Association, White Sulphur Springs, West Virginia, June 21, 1951.

TABLE III

METHOD OF ASSESSING COMBINED RATING *

Subjective Functional Result	Combined Rating				Grading
Excellent	0	1	2	4	0—Excellent
Good	1	2	3	4	1—Good
Fair	3	3	3	4	2—Fair
Poor	4	4	4	4	3—Poor
					4—Failure
Objective Functional Result	Excellent	Good	Fair	Poor	

* This table shows how the objective functional result and the subjective functional result, both measured by the numbers in the column headed *Grading*, are combined for the final rating. For a good objective functional result (1) and a good subjective functional result (1) the combined rating is 2, which equals fair. For a good objective functional result (1) combined with a fair subjective functional result (2) the combined rating is 3, which equals poor.

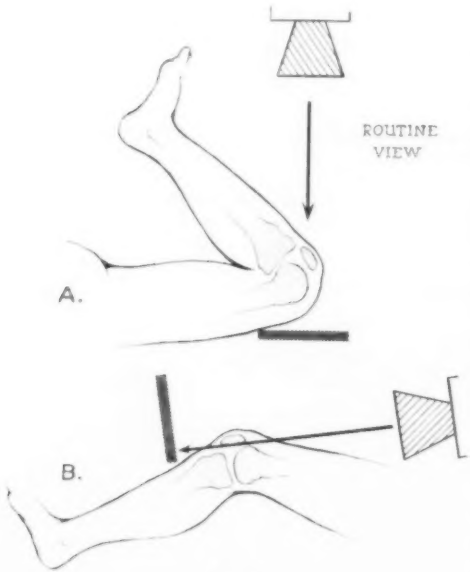

FIG. 1

A shows the routine "skyline view". Such a projection shows the tibial surface of the femoral condyles and an oblique view of the patella.

B shows the tangential view with the knee flexed 40 degrees.

years, with a range of six to twenty-one years in the males and three to twenty years in the females. Of the eight patients with congenital dislocation of the patella, there were three males and five females; the condition occurred bilaterally in two and unilaterally in six. In four cases the condition had remained untreated for several years; these patients afforded the opportunity to study the end result of the natural history of recurring dislocations. Three patients had not undergone operation at the time of the review, but were included in the series together with the ten patients who had been operated on within six months so that the mechanism of dislocation could be studied. In two instances the notes on the operation were inadequate; these patients are not included in the follow-up study. In all, it was possible to obtain an adequate follow-up study on forty-three operations performed for recurrent dislocation of the patella.

Assessment of results did not prove to be an easy task, as there was frequently considerable divergence between the objective functional result and the patient's own opinion. Accordingly, the results were assessed in two categories—the objective functional result (F.O.) and the subjective functional result (F.S.)—by the criteria outlined in Tables I and II. These two sets of results were then compounded to give a combined rating (Table III).

Eight different operative procedures were used (Table IV) either singly or in combinations. With such a small series, it was not possible to assess the merits of each technique. The over-all results, however, fell into two groups: a series of thirty-three cases with a

TABLE IV

CORRECTIVE PROCEDURES

	No. of Cases
Procedures to Re-align the Pull of the Quadriceps	
Transplantation of the tibial tuberosity alone	17
Transplantation of the tibial tuberosity and plication of the medial side of the capsule	14
Transplantation of the tibial tuberosity together with Krogius capsulorrhaphy	1
Supracondylar osteotomy alone	1
Supracondylar osteotomy with transplantation of the tibial tuberosity	1
Supracondylar osteotomy with capsulorrhaphy	1
Transplantation of the semitendinosus to the patella	1
Excision of Patella: Methods Used	
Patellectomy alone	1
Patellectomy, transplantation of tibial tuberosity, and capsulorrhaphy	3
Patellectomy and capsulorrhaphy	1
Miscellaneous	1
Albee's operation	1
Krogius capsulorrhaphy	1

TABLE V

RESULTS SIX MONTHS TO THREE YEARS AFTER OPERATION

Results	No. of Operations
Excellent	22
Good	6
Fair	2
Poor	2
Recurrence	1
Total	33

TABLE VI

RESULTS EIGHT YEARS TO TWENTY-TWO YEARS AFTER OPERATION

Results	No. of Operations
Excellent	0
Good	0
Fair	4
Poor	6
Total	10

short follow-up period which were reviewed from six months to three years after operation, and a series of ten cases with a long follow-up period which were reviewed between eight

FIG. 2

FIG. 3

Fig. 2: Roentgenogram of a normal patellofemoral joint made with the knee flexed 40 degrees.
Fig. 3: Loose bodies in relation to the medial edge of the patella in a case of recurrent dislocation. These loose bodies were not shown by the routine projection.

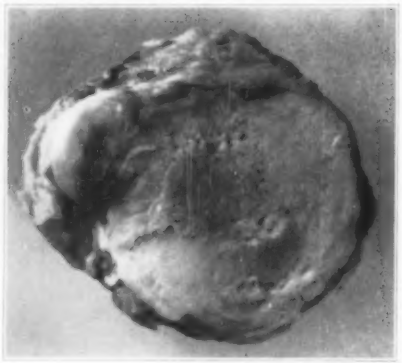

FIG. 4

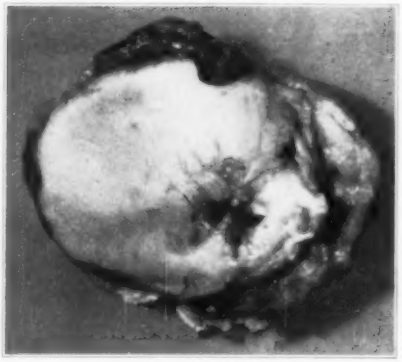

FIG. 5

Fig. 4: (Group I.) Fibrillation of articular cartilage of patella is evident.
Fig. 5: (Group II.) Crater in articular cartilage of patella on medial facet can be seen.

FIG. 6

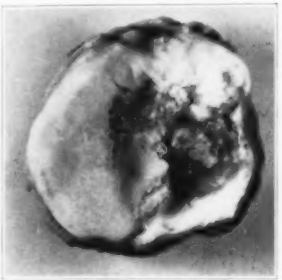

FIG. 7-A

Fig. 6: (Group II.) Slab roentgenogram of excised patella showing loose body in relation to medial edge.

Fig. 7-A: (Group II.) Photograph of excised patella shows articular cartilage worn away from medial side and underlying eburnated bone exposed.

Fig. 7-B: (Group II.) Slab roentgenogram of excised patella showing cartilage worn away on medial side, exposing the underlying bone to a considerable extent.

FIG. 7-B

and twenty-two years after operation.

The results in the series with a short follow-up period were encouraging. One patient unfortunately suffered a redislocation, but 85 per cent. had an excellent or good result (Table V).

The long-term results, however, did not present such a satisfactory picture (Table VI). All patients had clinical or roentgenographic evidence of osteo-arthritis and were handicapped in their activities to a varying extent. In two patients, the symptoms were so severe that it was thought advisable to do a patellectomy. At operation it was remarkable to note the amount of damage that had occurred in the knees, in spite of the fact that the patella had not dislocated again after the first operation.

PATHOLOGY

In view of these discouraging long-term results, the natural history of recurrent

FIG. 8

FIG. 9

Fig. 8: (Group III.) Tangential roentgenogram of the knee joint showing erosion of the lateral femoral condyle.

Fig. 9: (Group III.) Lateral roentgenogram of the knee shows spur of bone heaped up in relation to the superior border of the patellar facet of the femur (retouched).

Fig. 10: (Group IV.) Tangential roentgenogram of the knee joint shows marked patellofemoral arthritis with loss of the medial ridge of the patella.

FIG. 10

dislocation of the patella was investigated in more detail by studying the roentgenographic changes, as well as the pathological changes in the knee joint as seen at operation, and by studying the patella in those patients in whom the bone was excised. As the routine anteroposterior and lateral roentgenograms only reveal the gross changes in the articular surface of the patellofemoral joint, the most informative projection in investigating the degenerative changes is the so-called "skyline view".

For the routine skyline view of the patella, the patient lies face downward on the table with the cassette under the fully flexed knee. A roentgenogram made in such a way does not show the patellofemoral joint but shows the tibial surface of the femoral condyles and an oblique view of the femoral surface of the patella. The patellofemoral joint can only be demonstrated adequately by a tangential projection, with the knee flexed at 40 degrees (Fig. 1).

This projection has several advantages. It gives a detailed picture of the patellofemoral joint (Fig. 2). The central ray is parallel with the femoral surface of the patella and there is no overlap of bone shadows from the tibial condyles; the joint is therefore clearly defined and it is possible to assess early degenerative changes in the articular cartilage as reflected by narrowing of the joint space. Damage to the medial facet of the patella and loose bodies in this region can be demonstrated; these are not seen on the routine views because of overlap of bone shadows (Fig. 3).

FIG. 11

FIG. 12

FIG. 13

Fig. 11: (Group V.) Generalized osteoarthritis of the knee joint in a patient with recurrent dislocation of the patella of thirty years' standing.

Fig. 12: Roentgenogram of patient suffering from recurrent dislocation of the patella, with a large loose body in the knee joint.

Fig. 13. Loose body associated with a severely damaged articular cartilage in a patient with recurrent dislocation of the patella.

By combining a study of the roentgenograms with the pathological changes presented, it was possible to recognize a progressive degeneration of the patellofemoral joint. The degenerative changes that were seen fell into five groups.

Group I

In the first group the roentgenographic findings were within normal limits and the degenerative changes were demonstrated only at operation. The earliest changes were confined to the patella, and the first stage appeared to be a fibrillation and heaping up of the articular cartilage on the medial facet (Fig. 4). As this degeneration progressed, a small crater with soft fibrillated cartilage heaped up around its mouth appeared on the medial side of the patella (Fig. 5).

Group II

Roentgenograms of the knee showed evidence of degeneration. There was damage to the medial facet of the patella and a small loose body was sometimes seen in relation to the medial edge (Figs. 3 and 6). The changes in the articular cartilage were similar to those

FIG. 14-A

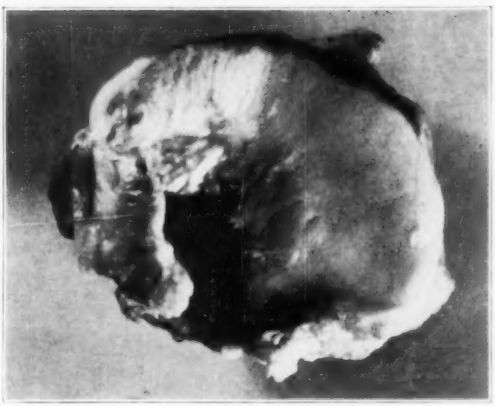

FIG. 14-B

FIG. 14-C

FIG. 14-D

Fig. 14-A: Roentgenogram of B. H., an eighteen-year-old girl with recurrent dislocation of the knee joint. The tangential roentgenogram shows that the patella is dislocating laterally but does not suggest any degenerative changes.

Fig. 14-B: The gross specimen showed a large crater in the patella which had not been suspected upon clinical examination.

Fig. 14-C: Slab sections of the excised patella. Note the cartilage erosion, the subchondral sclerosis, and the large detritus cyst.

Fig. 14-D: Slab roentgenogram of patella. Note the large subchondral cyst with the surrounding zone of bone sclerosis.

seen in the first group but slightly more severe. At first sight it seems strange that it should be the medial side of the patella which suffers most damage in a patient whose patella dislocates laterally. The reason probably lies in the mechanism of dislocation common to all these cases. For various reasons, such as aplasia of the lateral femoral condyle or a high-lying patella, on full extension of the knee, the patella loses the support of the lateral condyle and slips laterally. When the knee begins to flex, the patella remains in its lateral position until the knee has been flexed about fifteen degrees. It then suddenly slips over the lateral femoral condyle and remains in the intercondylar groove as long as flexion continues. This happens every time the knee is flexed and extended, and with every flexion movement the medial facet of the patella comes into traumatic contact with the lateral femoral condyle. If there is a sudden unguarded flexion movement, the patella is unable to regain the intercondylar groove and the knee is locked in flexion, with the patella dislocated laterally. This probably explains why the damage to the articular surface of the

FIG. 15

Drawing illustrating migration of the tibial tubercle when transplanted during the growth period.

patella appears first on the medial facet and is always greater on that side.

Group III

Roentgenograms of the knee showed degenerative changes in both the patella and the femur, and pathologically the subchondral bone, as well as the cartilage, showed evidence of damage. More and more cartilage had been worn away from the patella, and the underlying bone had become exposed, planed off, and eburnated (Figs. 7-A and 7-B). By this time, the articular cartilage of the femur had begun to share the same fate. Tangential roentgenograms of the knee joint showed damage to the lateral femoral condyle (Fig. 8). In this group, a lateral roentgenogram of the knee frequently showed a spur of bone heaped up at the upper border of the patellar surface of the femur. This is characteristic of the condition (Fig. 9).

Group IV

There was frank patellofemoral osteo-arthritis. The patella had lost its median ridge and its femoral surface was planed off and flat (Fig. 10).

Group V

In the fifth and final group, there was generalized osteo-arthritis of the knee joint (Fig. 11). This change was found in all patients who were seen with untreated recurrent dislocation of the patella of more than thirty years' standing. There were marked osteo-arthritic changes in the knee joint, and it would appear that osteo-arthritis starting in the patellofemoral joint may later involve the femorotibial joint.

DISCUSSION

What conclusions may be drawn from these pathological changes? How will they influence the choice of operation and what bearing will they have on the long-term result?

It is obvious that, if there are gross and irreversible changes, re-alignment of the patellar ligament or any other type of fixation operation will do nothing to influence the degeneration of the articular cartilage which must follow, and the long-term result must surely be disappointing. It is therefore essential to have some knowledge of the degree and extent of the degenerative changes in the joint at the time the patient comes to operation.

Some information can be obtained from the history and examination of the patient. When the condition has been present for a long time, the degenerative changes are likely to be severe; however, there was no exact correlation between the duration of the condition and the extent of articular damage. It did appear, however, that the degenerative changes

FIG. 16-A

FIG. 16-B

FIG. 16-C

Fig. 16-A: Case T. F. Roentgenogram made shortly after transplantation of the tibial tubercle in a patient aged nine. The site of transplantation is shown by the translucent area.

Figs. 16-B (right knee) and 16-C (left knee): Roentgenograms made three years after operation. Note how the site of the transplanted tubercle has migrated down the right leg, pulling the patella after it.

FIG. 17

FIG. 18

Fig. 17: The roentgenogram shows a large mass of bone at the site of the transplanted tubercle. This is probably a traction effect. With further growth of bone the transplanted tubercle has been pulled out like a traction epiphysis.

Fig. 18: The roentgenogram illustrates the forward tilting of the tibial plateau.

progressed more rapidly and were more severe in patients over sixteen.

The roentgenograms may give some indication of the changes which have occurred. The presence of a loose body is, of course, a good indication that the articular surfaces have been subjected to severe trauma (Figs. 12 and 13). Nevertheless, it is possible to have severe damage in the patellofemoral joint without any indication in the history or in the roentgenogram. The following case is instructive in this respect.

An eighteen-year-old girl was admitted with a history of four attacks of dislocation of her right patella. She had had no pain in her knee between attacks and physical examination revealed nothing except the abnormal movement of the patella on flexion and extension. The routine skyline roentgenogram did not reveal any abnormality. The 40-degree tangential view revealed that the patella was becoming dislocated laterally but did not suggest any degenerative changes (Fig. 14-A). It was surprising, therefore, to find at operation a large crater in the patellar cartilage (Fig. 14-B). The patella was excised as it was felt that, if it were left, the girl would be condemned to an early onset of osteo-arthritis. Further examination of the excised patella revealed that the damage was even more extensive than had been apparent at operation. There was marked subchondral sclerosis, and a large detritus cyst had formed in the underlying bone. This represented an irreversible change (Figs. 14-C and 14-D).

Many authors have devised operative procedures for recurrent dislocation of the patella, specifically designed to avoid opening the knee joint. This point of view has much to commend it, but unfortunately there is as yet no reliable means of telling whether the patellofemoral joint has been damaged, except by opening the joint and inspecting the articular surfaces. Degenerative changes are frequent and often severe. In view of this, it is suggested that the knee joint be opened and inspected in every case which comes to operation before the type of operative procedure is determined.

Ideally, these patients should be operated on before degenerative changes occur. This

is done only too infrequently. In this series, the average length of time between the first dislocation and the date of operation was seven years. Once degenerative changes have occurred, the surgeon has as yet only one means at his disposal of preventing extension of these degenerative processes,—that is, excision of the patella. Patellectomy alone is not enough. Recurrent dislocation of the patellar ligament can and does occur. The operation should be combined with measures to re-align the pull of the quadriceps; probably the easiest way of doing this is to transplant the tibial tubercle medially.

Transplantation of the tibial tubercle in children, whether patellectomy has been performed or not, has certain hazards. The ligamentum patellae is normally inserted into an extension of the tibial epiphysis or into a separate apophysis and by virtue of this insertion maintains its relationship to the knee joint during growth. If this insertion is transplanted during the growth period, it is possible that, with further growth of the bone, the new insertion will be pushed down the tibia, pulling the patella after it, or will be pulled out like a traction epiphysis (Fig. 15). In the combined series of recurrent dislocation of the patella and congenital dislocation of the patella, only six patients were found upon review in whom the tubercle had been transplanted during the growth period, more than two years previously in every case. However, of these six cases, five had some untoward result. In three, there was migration of the new insertion of the patellar ligament (Figs. 16-A, 16-B, and 16-C). The displacement of the patella which results gives rise to patellofemoral incongruity and may predispose to an early onset of osteo-arthritis. One case showed what appeared to be a traction effect (Fig. 17). In one case the operation had virtually acted as an anterior epiphysiodesis and had produced tilting of the tibial plateau (Fig. 18). It may be that in children one of the many other types of fixation operation is to be preferred.

CONCLUSIONS

This small series would seem to show that almost any operative technique adequately performed will prevent redislocation and give good early results. The long-term results, however, are very disappointing. A study of the natural history of the condition suggests that the reason for these poor results is that operations are performed late in the presence of unsuspected but severe degenerative changes.

It is suggested that the damage sustained by the articular surface of the patella is due much more to the abnormal excursions of the patella which occur with normal flexion and extension of the knee than to the occasional episodes of dislocation. In view of this, it is felt that surgical intervention should be undertaken early, in the hope that movement of the patella can be restored to normal before the articular cartilage is destroyed.

As it is impossible to assess accurately the degree and extent of articular degeneration by clinical means, it is suggested that the knee joint be opened and inspected in patients on whom operation is performed and, if there is marked damage, the patella should be excised, and the pull of the quadriceps should be re-aligned. Probably the easiest way of re-aligning the pull of the quadriceps is to transplant the tibial tubercle medially. This operation is very successful in adults but has certain hazards when performed on children. If the severe damage to the patellar cartilage which frequently occurs is unnoticed or is ignored, the patient will probably be condemned to an early onset of osteo-arthritis in the knee, with a final result as disappointing as those in patients on whom no operation has been performed.

NOTE: The author wishes to thank the members of the staff of the Royal National Orthopaedic Hospital for allowing him free access to their clinical material. In particular he would like to thank Mr. H. J. Seddon and Mr. K. I. Nissen for their advice and suggestions. Thanks are due to Dr. H. A. Sissons for preparing the pathological specimens and to Mr. R. Whitley for the photography.

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(*Discussion on page 976*)

BIPOLAR FRACTURE-DISLOCATION OF THE FOREARM *

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TRANSLATED FROM THE SPANISH BY HENRY MILCH, M.D., NEW YORK, N. Y.

Bipolar fracture-dislocation of the forearm is a rare injury which consists of fracture of the proximal third of the ulna with dislocation of the head of the radius and simultaneous fracture of the distal third of the radius with dislocation of the head of the ulna. This might be described as a concomitant Monteggia and Galeazzi fracture.

Monteggia's fracture is happily not common. Watson-Jones states that no lesion is more difficult to treat than this or more prone to result in failure. Only in children have there been reasonably satisfactory final results; in adults, on the contrary, the results have been almost universally bad. The special complications are: malunion of the ulna, irreducible dislocation of the radial head, stiffness and traumatic arthritis of the elbow, myositis ossificans around the radial head, ankylosis of the proximal radio-ulnar joint, radial palsy, synosteosis between radial and ulnar shafts, subluxation and dislocation of the distal end of the ulna, radial deviation of the hand, and stiffness of the wrist joint.

Galeazzi's fracture is even less common. Galeazzi first described this injury in a communication presented before the Lombard Surgical Society in 1934. It consists of a fracture of the radial shaft eight centimeters above the wrist joint combined with a dislocation of the ulnar head. The sequelae are similar to those of Monteggia's fracture except that it is the ulnar nerve instead of the radial nerve which is sometimes damaged. If one considers the complications associated with these fractures when they occur individually, the difficulties which arise when they occur in combination are not surprising. In general, patients with a severe fracture of the forearm are rarely able to give accurate details of their injury and the mechanism of these fractures is completely unknown.

Evans is in agreement with Messerer; he describes the mechanism of Monteggia's fracture in the following manner:

"When a patient falls forward on to the outstretched hand the forearm is already pronated and at the moment of impact the hand becomes relatively fixed to the ground. To the downward momentum of the falling body a rotation force is added when twisting of the trunk causes external rotation of the humerus and ulna. . . . If this force continues until the normal range of pronation at the radio-ulnar joints is expended, something must give. The ulna cannot rotate, because it is fixed below by the ulnar carpal ligament and above by its articulation with the humerus. The ulna is therefore liable to fracture, and the combination of the rotation force and of the bending force set up by longitudinal compression may produce an oblique, transverse or butterfly fracture in accordance with the principles set out by Messerer . . . [Fig. 1]. At the same time the radius is forced into extreme pronation and lies across the ulna, at the junction of the upper and middle thirds. As the ulna fractures, the two bones come into contact, and the point of contact forms a fulcrum over which the upper end of the radius is forced forward. As the pronation force continues, the radius is either levered forward out of the superior radio-ulnar joint or is fractured in its upper third.

On theoretical grounds, then, one would expect forced pronation to cause one of three injuries, all of which are well-known: 1) fracture of the ulna in its middle third with backward angulation and anterior dislocation of the head of the radius—the anterior Monteggia fracture; occasionally the head or epiphysis of the radius is damaged at the same time; 2) fracture of the ulna as above with a high fracture of the shaft of the radius; 3) anterior dislocation of the head of the radius without fracture of the ulna."

Without entering into a discussion whether Monteggia's fracture is always produced by the mechanism described by Evans or whether at times it results from a direct blow on the dorsum of the forearm as other authors maintain, the experimental evidence produced by Evans certainly tends to support his theory that the pronator force is funda-

* Received for publication November 24, 1951. Presented to the *Sociedad Argentina de Ortopedia y Traumatologia*, at Córdoba, Argentina, December 7, 1951.

mental. By analogous reasoning fractures of the radius with dislocation of the ulnar head (Galeazzi's fracture) may be explained. This theory therefore serves to explain the mechanism of the bipolar fracture-dislocation.

Bipolar fracture-dislocation of the forearm is an injury associated with modern rapid transportation. It results from two opposing forces acting on the forearm. The patient is usually seated in a vehicle with the elbow, flexed to a right angle, resting on the window ledge and projecting through the window with the hand pronated and in hyperextension on the hand rest. When the passing vehicle "sideswipes" the car in which the man is sitting, the elbow is struck from behind and is forcibly impacted against the hand, which is firmly held in pronation. The opposing forces act in a manner similar to that described by Evans for Monteggia's fracture (Fig. 2).

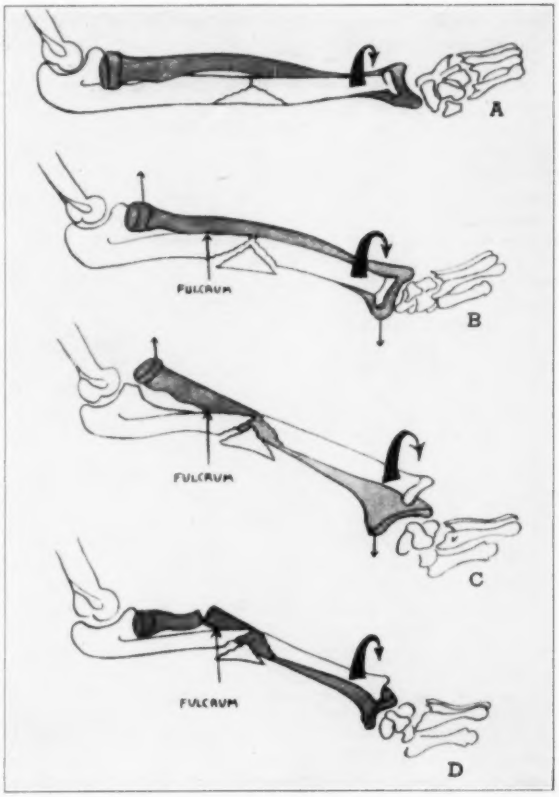

FIG. 1

The diagram shows the mechanism of trauma to the forearm in pronation. The bones are seen in the lateral view. In pronation the ulna and radius cross at the juncture of the middle and upper thirds. *A:* The ulna may fracture by forced rotation or by angulation. *B:* At the same time, the proximal third of the ulna acts as a fulcrum against the proximal end of the radius, forcing it forward if pronation continues. *C:* This results in the dislocation of the radial head, or, *D,* in a transverse fracture of the proximal end. (Reproduced from E. M. Evans, Pronation Injuries of the Forearm, with special reference to the Anterior Monteggia Fracture, *The Journal of Bone and Joint Surgery,* 31-B: 578, 1949.)

There is thus produced first a fracture of the upper third of the ulna with forward dislocation of the radial head. But as the forearm is maintained in the same position while the impacting force continues, the dislocated radial head is driven against the anterior aspect of the distal end of the humerus and the fixed lower end of the radius fractures in its lower third. With continuation of this force the fragment acts as a fulcrum over which the ulnar head is dislocated anteriorly and medially (Fig. 3).

We have observed three patients, two of whom we were able to follow.

The first was a man fifty-one years old who nine years ago, while holding his hand as previously described (Fig. 2), was struck on the forearm by another vehicle and suffered a bipolar fracture-dislocation of the forearm. He was treated immediately by a competent surgeon who made roentgenograms and diagnosed a fracture of the upper portion of the ulna with dislocation of the radial head, compound fracture of the inferior third of the radius, profuse hemorrhage, and loss of tissue in the lower portion of the wound. The hand was flail, cold, and cyanotic. No pulse was perceptible. The fracture was tentatively reduced and fixed in plaster. Six hours later the fingers had improved in appearance and were warm. During the next week, the color

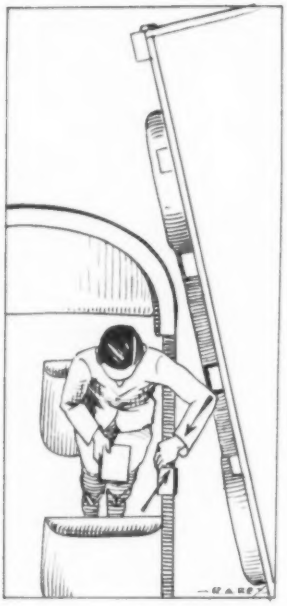

FIG. 2

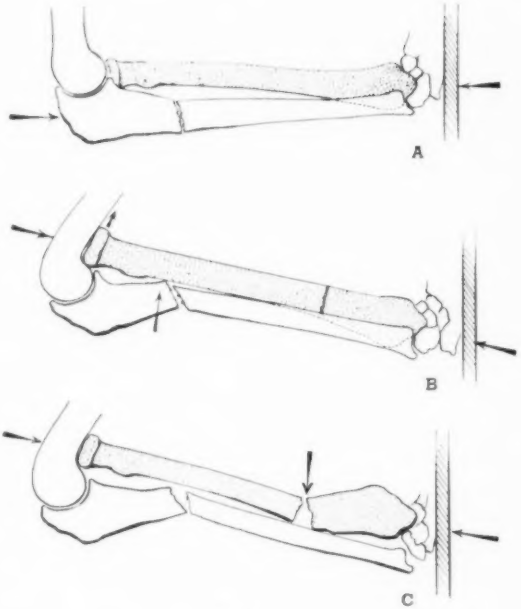

FIG. 3

Fig. 2: Diagram illustrating patient with forearm on window ledge and hand resting on a lower support. Arrows indicate direction of opposing forces in the impact by another vehicle against the elbow.

Fig. 3: Diagram of lateral view of forearm. *A:* The arrows indicate the direction of opposing forces. *B:* Fracture of the superior third of the ulna with dislocation of the radial head (Monteggia's fracture). *C:* Fracture of the lower third of the radius with dislocation of the ulnar head (Galleazzi's fracture).

of the skin slowly improved and the oedema diminished. On the seventh day the cast was opened and under general anaesthesia it was possible to reduce the radial dislocation and to place the radial fragments in a better position. Although a satisfactory reduction was not obtained, it was fortunate that amputation was avoided.

The patient was then referred to the author eighteen days after the accident. Roentgenograms (Figs. 4-A and 4-B) made on December 2, 1941, which the patient brought with him, showed a bipolar fracture-dislocation of the right forearm. After removal of the plaster considerable oedema of the whole limb was noted, particularly in the elbow, distal third of the forearm, hand, and fingers. On the anterior surface of the forearm in its lower third there was a foul-smelling wound measuring six by eight centimeters with obvious tissue gangrene. The radial pulse was not palpated. The wound was treated through a windowed plaster cast. At the end of twenty days gangrenous tissue was excised and Thiersch grafting was performed. Ten days later active motion exercises were instituted. On February 2, 1942, the plaster was removed. Roentgenograms (Figs. 4-C and 4-D) disclosed the unreduced bipolar fracture-dislocation of the forearm. On February 7, 1942, fifty-five days after injury, all skin wounds were closed and the superior fracture-dislocation was reduced surgically. Osteosynthesis of the ulna and reduction of the radial head by means of a fascial graft was performed by the method of Boyd (Fig. 4-E) on March 17, 1942. Four months later, on July 15, 1942, the elbow was ankylosed at 90 degrees. All motion of the elbow, as well as pronation and supination of the forearm, was absent. Motion of flexion and extension of the wrist was markedly limited. The fingers had recovered their mobility.

The roentgenogram (Fig. 4-F) revealed calcification around the anterior aspect of the humerus as well as about the head of the radius. The articular space of the elbow was markedly narrowed and was becoming ankylosed. The radial head was dislocated forward and there was absorption of bone at the fracture site in the ulna. The fracture of the lower third of the radius had united with shortening of one centimeter and there was a radial deviation of 20 degrees with lateral displacement in the width of the diaphysis.

After two years the elbow was completely ankylosed at 90 degrees. Pronation and supination of the forearm were lost and the wrist was fused in mid-pronation. The fingers had preserved more than 80 per cent of their mobility. Roentgenograms (Fig. 4-H) revealed bony ankylosis of the elbow. The plate was still

in situ despite the fact that one of the olecranon bolts had come loose. There was absorption of bone at the fracture site in the ulna, but apparently the plate had prevented loss of position. Eight years later the plate and bolts had still caused no difficulty.

The second case was that of a female, twenty-three years old, who suffered an injury on November 15, 1941. She was sitting in the vehicle with her forearm in the position shown in Figure 2 when the impacting force—another automobile—struck her elbow. She immediately experienced intense pain in her right forearm and realized that she had a compound fracture, for she saw the ends of the broken bone covered by blood. The wound was irrigated with alcohol and pressure was applied. She was taken to a first-aid station where the wound was dressed and was then sent to the Hospital San Martin where she was operated upon immediately. Bleeding vessels were ligated and severed nerves and tendons were sutured. The arm was immobilized in a windowed cast. Sulfonamides were used both locally and systemically and tetanus antitoxin and antigen were given. The wound became septic and drained for six months. During this period the arm was immobilized in an aeroplane splint with skeletal traction. After six months when the wound was healed, a circular cast was applied. A few days later a graft from the left tibia was inserted through the window in the cast.

A hematoma developed in the wound and was evacuated in forty-eight hours. However, the wound became septic and was healed first in a windowed cast and then in a closed circular cast with transfixion wires for one year. At this time there was still some drainage and non-union. Another bone graft from the right tibia was inserted but suppuration persisted during the ensuing year with the gradual extrusion of necrotic bone fragments and on one occasion a wire ligature. Another operation was then proposed, but the patient refused and consulted the author.

On April 12, 1945, two years and five months after the accident, the patient presented herself with a circular fenestrated cast which covered elbow, forearm, and hand. The roentgenogram (Fig. 5-A) made on April 12, 1945, showed a bipolar fracture-dislocation of the forearm and in the middle of the ulna a defect in which the graft was observed as a sequestrum. There was decalcification and osteoporosis in the bones of the wrist and hand. When the cast was removed, the operative scar over the ulna was found to be open. On the radial side there was a contracted scar in the middle third. Abnormal movement of the forearm was present due to non-union and loss of continuity of both bones. Roentgenograms made two years and five months after injury showed a typical Galeazzi fracture, that is, fracture of the radius eight centimeters from the radiocarpal articulation and dislocation of the head of the ulna. The Monteggia fracture was less obvious since apparently the ulna had fractured in two places, at the juncture of the upper and middle thirds and just distal to the olecranon. However, because of the concomitant dislocation of the head of the radius, the injury was a typical Monteggia fracture.

The graft and fatty tissue were removed under pentothal anaesthesia. After four weeks (January 15, 1946) the wound had healed. Roentgenograms (Fig. 5-C) showed the large defect in the ulna. Nine months later on February 7, 1946, the defect was filled with a graft from the fibula (Fig. 5-D). After eight months, October 15, 1946, the graft had taken at both extremities (Fig. 5-E). Four months later the retracted scar on the radial side of the forearm was excised and a skin graft from the abdomen was applied. The wires were also removed. A roentgenogram made on April 22, 1947 (Fig. 5-F), shows the medullary canal of the fibula continuous with that of the ulna. After two months, a double onlay iliac graft was applied to the pseudarthrosis in the radius, on June 19, 1947 (Fig. 5-G). Six months later (December 4, 1947) solid union was evident by x-ray (Fig. 5-H). Both the wrist and the elbow were ankylosed with the elbow at right angles and the wrist in intermediate position without pronation or supination. However, the patient was able to do manual work and to resume her work as a piano teacher.

These two cases and a third which we have not been able to document demonstrate the existence of this entity, which is caused by a clearly established mechanism. Although it is not a common injury it should be recognized since good results are possible with correct treatment from the onset. Once the lesion has been recognized, the compound fracture should be debrided according to the generally accepted techniques. Thereafter, the lower end of the ulna should be resected to facilitate a closed reduction of the Monteggia fracture. The dislocation of the radial head can be reduced by supinating the forearm and applying pressure over the radial head. Except for the resection of the inferior extremity of the ulna, this is the currently accepted technique for the reduction of the majority of Monteggia fractures. The distal fragment of the fractured radius is pulled into pronation by the action of the pronator quadratus. This frees the lower end of the ulna from all restraint. To prevent this, the arm should be maintained in supination by a split circular plaster mold. If satisfactory union of the fractures in the ulna and radius occurs, good flexion-extension of the elbow and wrist and pronation-supination of the forearm will

FIG. 4-A

FIG. 4-B

FIG. 4-C

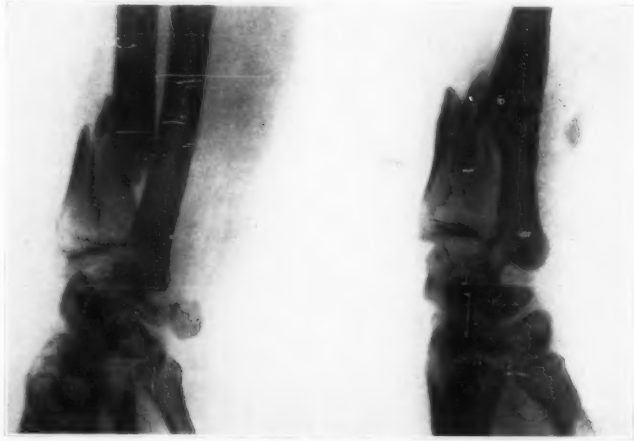

FIG. 4-D

Fig. 4-A: Lateral roentgenogram showing fracture of the proximal third of the ulna and dislocation of the radial head.
Fig. 4-B: Fracture of distal third of the radius and dislocation of the ulnar head.
Fig. 4-C: Lateral roentgenogram showing fracture-dislocation of Monteggia type.
Fig. 4-D: Roentgenogram showing Galleazzi type of fracture-dislocation in the same arm, eighteen days after injury.
Fig. 4-E: Lateral and anteroposterior roentgenograms showing the radial head after reduction. Ulnar fragments are aligned and maintained by wire and a plate with four bolts.
Fig. 4-F: Anteroposterior and lateral roentgenograms showing antehumeral calcification about the elbow and radial head. The latter is dislocated anteriorly. Note the narrowing of the joint space and lacunar rarefaction at the ulnar fracture site.

FIG. 4-E

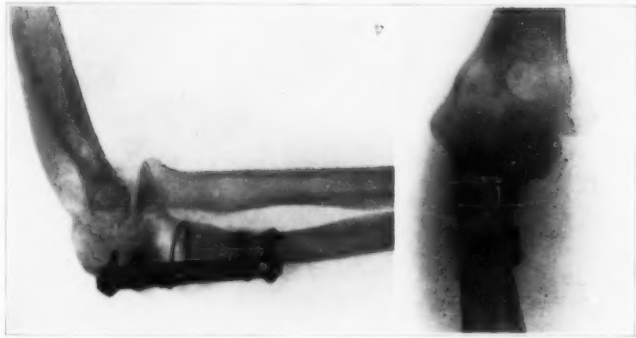

FIG. 4-F

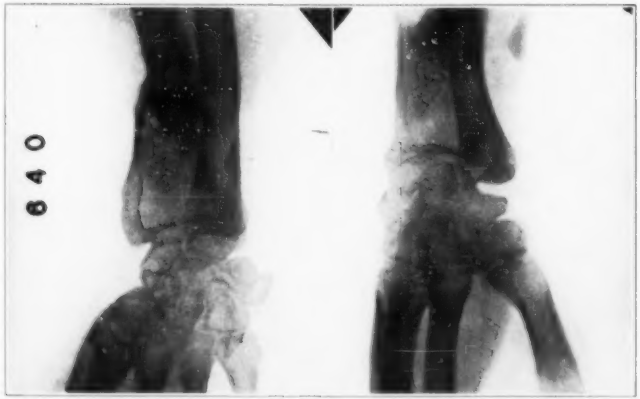

FIG. 4-G

Anteroposterior and lateral roentgenograms of the lower third. Fracture of the lower third united with one centimeter's shortening, varus angulation of 20 degrees, and lateral displacement the width of the diaphysis.

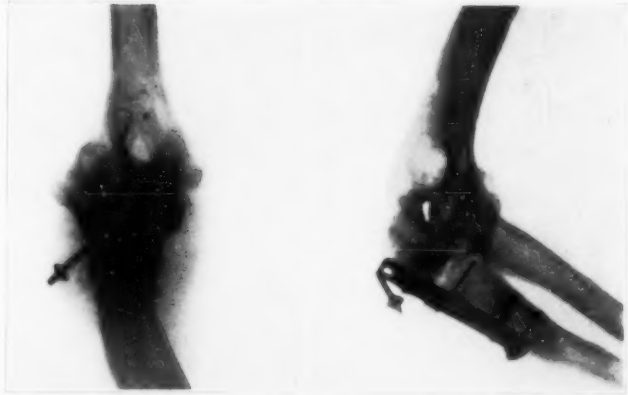

FIG. 4-H

Anteroposterior and lateral roentgenograms, showing ankylosis of the elbow. The plate is in position with the upper bolt loose. Loss of three millimeters in length of the ulna at the fracture site.

FIG. 5-A

Lateral roentgenogram showing a Monteggia fracture and the defect in the middle third of the ulna.

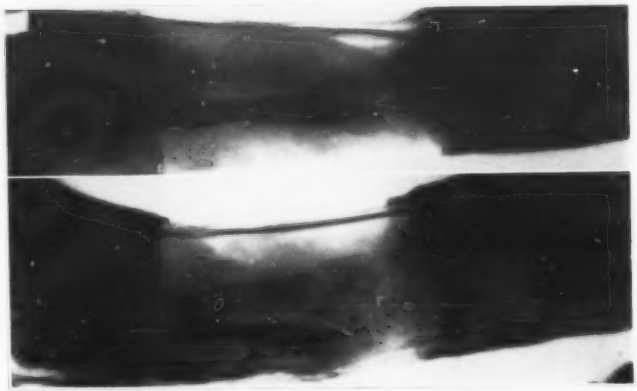

FIG. 5-B

Anteroposterior and lateral views, showing a Galeazzi type of fracture-dislocation.

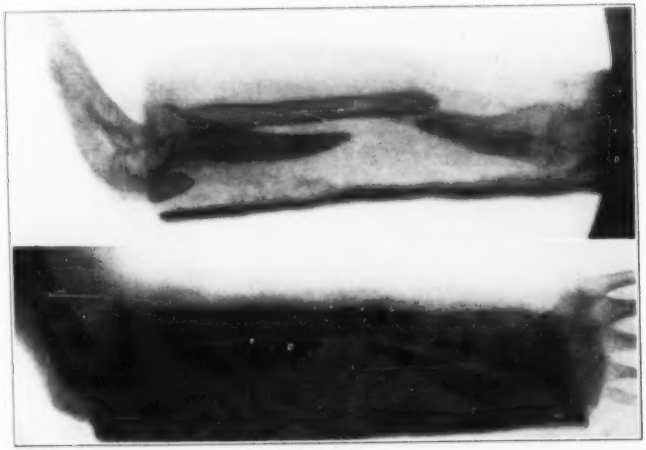

FIG. 5-C

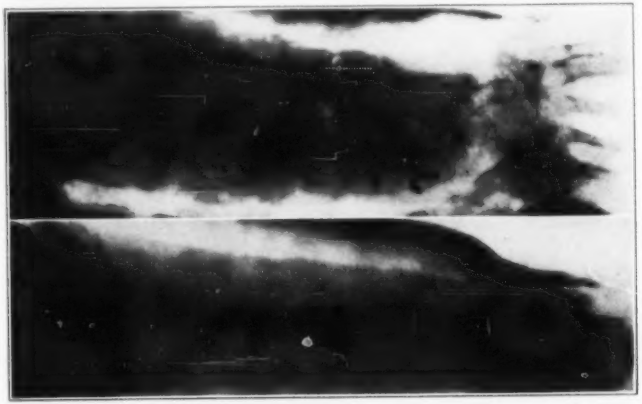

FIG. 5-D

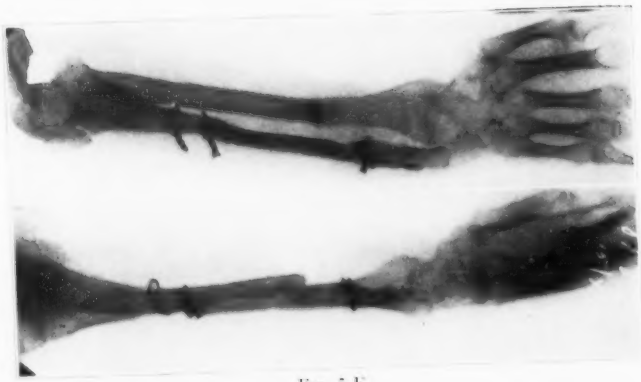

FIG. 5-E

FIG. 5-F

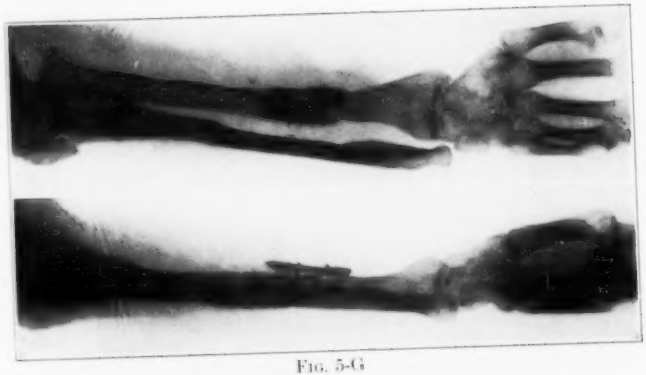

FIG. 5-G

FIG. 5-H

Fig. 5-C: Showing large defect in the ulna.
Fig. 5-D: Fibular graft mortised snugly between the ulnar fragments and held by four ligatures of stainless steel.
Fig. 5-E: Roentgenograms after eight months, showing fibular graft united at both ends.
Fig. 5-F: Roentgenograms after fourteen months, showing the continuity of the medullary canal of the fibular graft with that of the ulna.
Fig. 5-G: Anteroposterior and lateral views, showing dual iliac grafts placed at the site of the pseudarthrosis of the radius.
Fig. 5-H: Anteroposterior and lateral roentgenograms showing healing of the pseudarthrosis.

be obtained. The only mishaps which may occur are malunion or pseudarthrosis of the radius, but these complications may be easily corrected later.

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DISCUSSION

RECURRENT DISLOCATION OF THE PATELLA

(*Continued from page 967*)

DR. FREMONT A. CHANDLER, CHICAGO, ILLINOIS: I wish to take this opportunity to emphasize that there is a possibility of arresting growth of the upper tibial epiphysis by removal of the block of bone which is attached to the patellar ligament. Some years ago, in correcting patellar displacement in spastic paralysis, I found to my regret that arrest of growth did occur when this epiphysis was disturbed. I have attempted on several occasions since to transmit this observation to others and thereby prevent deformities of the upper tibial plateau.

DR. JOHN L. MCDONALD, TORONTO, ONTARIO: I would like to emphasize a point which was brought up in Dr. Macnab's paper,—namely, the importance of a long follow-up report on these cases; if he had been content to accept the three-year follow-up, he would have had an entirely wrong picture of the condition. In the long-term follow-up, up to twenty-two years, it was very evident that a great many patients presented gross osteo-arthritis of the knee joint.

I would also like to emphasize the importance of making roentgenograms in cases of suspected slipping of the patella. I think the term "recurring dislocation" should be modified to include those cases in which there is an increase in the lateral play of the patella in flexion and extension of the knee. As we all know, this is very common, particularly in women, and it is interesting to note that in Dr. Macnab's group over 80 per cent. of the cases were in women. I think that it would be advisable in all cases of increased lateral play at the patella to make careful roentgenographic studies and particularly to study the tangential view, observing the space between the articular surface of the medial facets of the patella and the adjacent surface of the femoral condyle. I think that, if these cases could be recognized at that stage and a suitable operative procedure could be carried out, we might save a lot of these knees from subsequent permanent damage. In regard to the various operative procedures to be used in recurring dislocation of the patella, I think that perhaps the one most favored at the present time is transplantation of the insertion of the patellar ligament with the tibial tubercle. This leaves much to be desired, as Dr. Macnab has pointed out, particularly if it is done in the growing child. I have seen, in addition to the disastrous results that occurred in three of Dr. Macnab's patients, one case in which the tibia rotated laterally on the knee, so that the patient was left with an outward rotation of the tibia in relation to the line of the femur.

DR. MACNAB (closing): In answer to Dr. McDonald's queries, while taking these views tangentially at 40 degrees in order to get some roentgenograms of non-dislocating knees, we made some x-rays of patients with osteo-arthritis. It was interesting to note that in these, although they gave no history of dislocation, the films showed in several instances that the patella was dislocating laterally. It is tempting to speculate that some of these cases of osteo-arthritis are due to subclinical luxations of the patella.

BLASTOMYCOTIC OSTEOMYELITIS

With a Case Report

BY RICHARD H. HALL, M.D., AND JOSEPH MENDELOFF, M.D., FAYETTEVILLE, NORTH CAROLINA

From the Department of Orthopaedics and the Department of Pathology, Veterans Administration Hospital, Fayetteville

Two main clinical forms of North American blastomycosis are described in the literature: systemic and dermal [5]. The following report presents a case usually included or described as systemic, although it is at variance with the typical.

CASE REPORT

History

The patient was a white male, twenty-one years old. In April 1948 he began to experience swelling and pain in the right foot. A swollen area appeared over his longitudinal arch. Two months later drainage occurred spontaneously at this site. This was soon followed by a red, swollen area on the lateral side of the same foot. Following surgical drainage there was no healing and the patient was referred to our Hospital in August 1948.

The patient denied trauma to the foot, walking barefooted, and any recent or severe episodes of respiratory disease.

Physical Examination

He was a slightly underweight male with the peculiar pallor often observed in those chronically ill. The only other positive finding consisted of draining sinuses on both sides of the right foot (Fig. 1).

Roentgenographic Findings

On admission there was marked osteoporosis of the tarsal bones of the right foot; the second and third cuneiforms were not discernible and apparently had been destroyed. There was marked sclerosis of the talus and calcaneus. The proximal ends of the second and third metatarsals were partially destroyed (Fig. 2). Pulmonary findings at this time were reported as negative. Serial roentgenograms of the skeleton showed no additional lesions.

Laboratory Findings

The urinalysis was completely negative and the red-cell count was normal, including the differential count. The sedimentation rate was 26 (corrected Wintrobe method). The Kahn test was negative.

FIG. 1

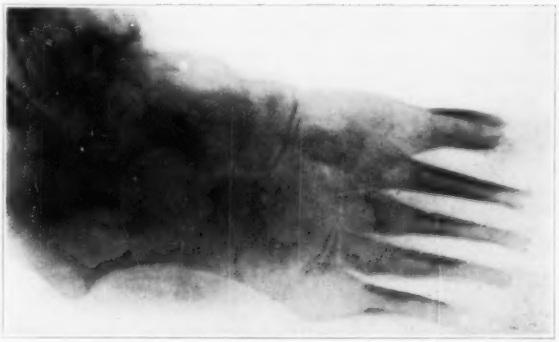

FIG. 2

Fig. 1: The right foot represented a multiple draining sinus tract.

Fig. 2: Roentgenogram made at admission, showing destructive bone lesions and osteoporosis of the right foot.

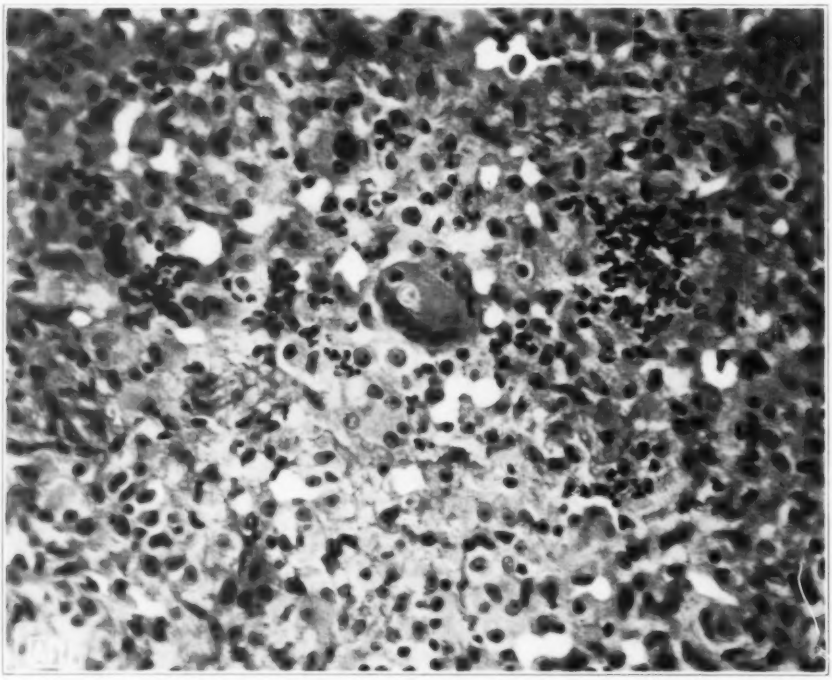

FIG. 3

Photomicrograph (× 300) showing the granulomatous lesion with a giant cell containing a budding parasite. (From the Armed Forces Institute of Pathology, Washington, D. C.)

Diagnosis

A biopsy curettage of one of the sinuses was performed September 17, 1948. The pathological report was that the material obtained consisted of small fragments of pinkish and yellowish-gray fragments of soft tissue and a small chip of bone. This tissue presented no unusual gross features.

Microscopic examination revealed the material to be entirely granulomatous and to contain small bone fragments. There were numerous histiocytes, epithelioid cells, polymorphonuclear cells, and lymphocytes with some fibroblastic reaction. In some places there were small collections of "foam" cells. Scattered throughout there were moderate numbers of giant cells and many micro-abscesses. Within the giant cells and also free in the surrounding granulomatous tissue there were parasitic structures consisting of small spherical bodies which had double-contoured capsules and which contained central clumps of basophilic material. Small, single buds were present on occasional parasites (Fig. 3).

Some of the same tissue was also cultured on blood agar plates and Sabouraud's medium (at both incubator and room temperature). Petragnani's medium was also used, but produced no growths.

The growths recovered from the blood agar plates and Sabouraud's medium were identified as *Blastomyces dermatitidis*. Confirmation was made by Dr. Conant of Duke University Medical College.

Further diagnostic studies on this patient consisted of a positive skin test of 1.5 centimeters with blastomycin vaccine. A complement-fixation test for *Blastomyces dermatitidis* was positive. A tuberculin skin test was negative.

Therapy

Treatment consisted in applying repeated casts, either windowed or bivalved for dressing. After the patient had been desensitized with vaccine, he was started on potassium iodide. The saturated solution of potassium iodide was begun on November 18, 1948, the dosage at first being ten drops three times daily. This was gradually increased at the rate of three drops a day (that is, one additional drop with each dose) until the patient was receiving sixty drops three times daily. He was maintained at this dosage for three months. A right lumbar sympathectomy was performed February 7, 1949, in the hope of improving foot circulation and indirectly alleviating the infection. Circulation improved, but there was no apparent clinical change in the

infection. Amputation was considered on several occasions, but each time it was deferred. It was felt that a course of x-ray therapy should be tried before amputation was considered. On June 1 and 3, 1949, twenty-five roentgen units were administered to the lateral and medial aspects of the foot.* Potassium iodide therapy was resumed from June 8 to July 23, 1949. The starting dose was again ten drops three times a day. This was increased by a total of three additional drops a day (one with each dose) until he was receiving sixty drops three times daily. This final dosage was maintained until July 23, 1949.

Roentgenograms after Admission

Serial roentgenograms of the foot upon review showed evidence of beginning re-formation and sharper outlines of the proximal ends of the metatarsals as early as April 1949. By October there was very definite increase in bone density, trabeculation, and bone demarcation. Improvement continued until by August 1951 there was no remaining evidence of infection (Fig. 4). All of the metatarsals were regenerated with good trabeculation, but presented less density than normal bone. The second cuneiform was completely regenerated. The chief loss of bone appeared to be the distal two thirds of the third cuneiform.

Review of serial roentgenograms of the chest initially showed a linear strand of increased density in the medial half of the right lung field. It measured 6.5 by 0.3 centimeters and overlaid the posterior segment of the right eighth rib. The remainder of all lung fields was clear. There was never any remarkable change in this linear area of density.

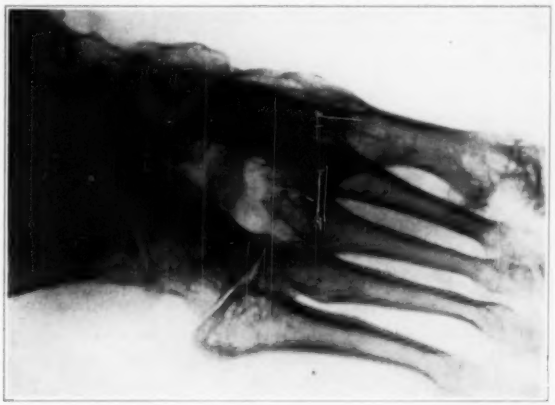

FIG. 4

Roentgenogram of the right foot, made in August 1951, three years after admission, showing regeneration and absence of the destructive inflammatory process.

Laboratory Findings after Admission

Serial blood cultures were negative. Cultures from the draining sinuses were negative for fungi in April and June of 1949, but *Staphylococcus aureus* was once reported. One direct smear taken in May 1949 showed a finding of budding yeast-like cells resembling *Blastomyces dermatitidis*. Complement-fixation tests for *Blastomyces dermatitidis* were negative on July 25, 1949, and February 5, 1951. A skin test performed on April 12, 1950, with 0.1 cubic centimeter of antigen revealed a one-centimeter zone of erythema in twenty-four hours, and this zone persisted at the end of forty-eight hours.

Clinical Course

None of the methods of treatment used was in itself satisfactory. The amount of drainage fluctuated over a long period of time. Some sinuses closed for short periods and then reopened or new ones appeared; all the sinuses, however, were confined to the same area of the right foot. In early August of 1949 the sinuses closed one by one until, after two weeks, all were completely healed without drainage or fluctuation. The foot has remained healed with no signs of infection. Because the involved foot had soft-tissue atrophy, a heightened arch, and some joint stiffness, the patient was fitted with a special orthopaedic shoe. He walked for long distances without a limp, and could stand indefinitely without symptoms.

The patient at no time had pulmonary symptoms and never a productive cough; presumably his primary focus was pulmonary, but was clinically silent.

DISCUSSION

The literature reports a uniformly poor prognosis—from 85 to 92 per cent.—for systemic blastomycosis. Actually, the prognosis appears to depend upon the dissemination. Upon reviewing ninety-one systemic cases, including our own, we find that those patients with extensive dissemination usually reach a fatal outcome quite rapidly, whereas those with localized involvement are living after years of observation [1,15] and in some cases their

*Through the courtesy of Veterans Administration Hospital, Richmond, Virginia.

lesions are arrested. Nine focal lesions of the osteomyelitic type were reported to be arrested [2,5,6,7,11,12] and ten other patients with this type of lesion were living at the time of the reports [1,3,4,5,7,11,12,13,15]. The other seventy patients with widely disseminated lesions were reported dead or moribund. There were only ten cases in which less vital structures only, such as bones, skin, lungs, peritoneum, and genitalia were found to be involved at autopsy. The remainder of the patients on whom autopsy was performed had involvement of liver, kidneys, heart, pericardium, brain, or meninges. Thus we see that, if the disease remains focalized, involving only small areas of lungs, skin, bone, genitalia, and the like, the mortality rate is reduced and the rate of cure is almost 50 per cent. Whereas, if the disease becomes widely disseminated even in the skin alone, or if it involves such organs as the liver, heart, or kidneys, it is usually fatal within a few months.

Surgically it is possible to remove foci of infection at times and thus prevent further dissemination. However, we feel that each case should be carefully studied from all aspects and that, as a general rule, surgery should be perhaps even more conservative than in tuberculosis.

Desensitization and iodide therapy are worth trying. Beyond that one can only add general supportive measures.

We wish to emphasize that cases of the type we have reported can occur in the presence of a clinically and objectively silent primary lesion, usually a pulmonary lesion. Awareness of this indicates the need for constant observation and search.

CONCLUSION

The prognosis for osteomyelitis due to *Blastomyces dermatitidis* is not necessarily poor and depends on the degree of dissemination.

The authors wish to stress the close kinship between blastomycotic osteomyelitis and tuberculous osteomyelitis, in pathogenesis, differential diagnosis, and treatment.

Surgery for this disease should be most judicious.

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END-RESULT STUDY OF THE TREATMENT OF HERNIATED NUCLEUS PULPOSUS BY EXCISION WITH FUSION AND WITHOUT FUSION *

BY THE RESEARCH COMMITTEE OF THE AMERICAN ORTHOPAEDIC ASSOCIATION,
I. WILLIAM NACHLAS, M.D., CHAIRMAN **

With the Clinical Assistance of J. E. Simpson, M.D.

Recognition of the role of the herniated nucleus pulposus in the syndrome of low-back pain with sciatica has brought us the problem of treatment. It is generally agreed that conservative methods should be tried, but it is conceded that in a selected number of cases surgical intervention is necessary. There is, however, some controversy over the procedure of choice. In general, there are two schools of thought on this subject. One group feels that the offending disc should be removed and that the structural weakness left by this removal should be corrected by fusion of the adjacent vertebrae. The other group believes that disc excision is all that is necessary. Both methods of treatment are being used and each has its advocates. But, in spite of a number of reports that have been made by various clinics, there are many surgeons for whom the question is still open. Because of this, The American Orthopaedic Association has authorized its Research Committee to investigate this problem, the National Research Council has approved the study, and the Veterans Administration has undertaken to finance it. Many clinics throughout the country have offered to make their records and patients available for this investigation.

The Research Committee approached the problem statistically, that is, by comparing the end results obtained in a group of patients treated by disc removal alone with those in a group of patients on whom a fusion operation was performed immediately after the disc was removed. Since long-term results were considered desirable, it was decided to include only those patients with operations performed more than five years ago. Furthermore, it was believed best to avoid the complications which occurred during the earlier, experimental period. Consequently the study was limited to operative cases of the five-year period between January 1, 1941, and January 1, 1946. The upper age limit for our patients was set at forty-five years, to reduce the incidence of physiological degenerative manifestations. Since our interest was in the results of methods rather than those of a single clinic, it was decided to obtain the case material from a number of well recognized institutions with fully qualified surgeons.

As a matter of expediency the institutions chosen were in the eastern portion of the United States (Table I). Reliance on hospital records and questionnaires alone was considered inadequate; instead, personal interviews with and examinations of the patients were deemed necessary. In the interest of uniformity and to avoid bias, a competent orthopaedist not previously connected with the institutions and without fixed convictions on the subject was found (J. E. S.) and to him was entrusted the survey of the records, the interviews, and the examinations. Data sheets were prepared by the Committee and were used by him to record his findings at each interview. The completed sheets were returned to the Committee, which evaluated the end result for each patient without reference to the operative procedure and in accordance with a pre-arranged standard for rating.

* The United States Veterans Administration approved this investigation and financed it.

** This study has been the project of the Research Committee for four years. The members of the Committee for the past year have been Dr. C. Howard Hatcher, Dr. V. T. Inman, and Dr. I. William Nachlas, Chairman. During the four-year period the Committee membership has included Dr. Halford Hallock, Dr. W. Ward Plummer, and the late Dr. James Toumey, to whom credit is given for their participation. Valuable assistance and guidance were given by the biostatisticians of The Johns Hopkins Hospital, Dr. R. V. Rider and Dr. Clifford A. Bachrach.

DISC SURGERY INVESTIGATION

Data Sheet

Name:
Address:
Age: Sex: Color: Height: Weight: Clinic: Clinic No.:
Occupation: Operation Date:
Remarks: Excision: Fusion:
Legal:
Compensation:

Original Record

History Date:

Onset
Date: Acute: Trauma: Insidious:
Symptoms
Back pain: Location: Referred pain: Location:
Disability:
Effects of rest: Effects of activity:
Course
Recurrences:
Remarks:

Physical Examination

Posture
A-P Curves: Trunk List: Lateral Curve: Pelvic Tilt:
Spasm Location: Severity:
Tenderness Location: Severity:
Mobility
Flexion: Pain: Lateral Bend R: Pain:
Extension: Pain: Lateral Bend L: Pain:
Neurological
Reflexes: Knee R: Angle R:
Knee L: Ankle L:
Hypaesthesia: Muscle weakness: Anaesthesia: Atrophy:
Leverage Tests

Laboratory Findings

X-Ray

Myelogram
Date: Type: Was opaque medium removed?
Lumbar Puncture
Total protein:

Treatment

Conservative Type: Effects:
Operative Date: Anaesthesia: Location: Surgeon:
Approach Laminectomy: Hemi-laminectomy:
Partial laminectomy: Ligamentous:
Findings Disc: Type:
Level:
Removal Simple Excision: Superficial curettement: Thorough curettement:

Fusion Type: Location: Surgeon:
Complications Immediate: Late:
Remarks:

Hospital Course

Immobilization Type: Duration:
Physical Therapy Type: Duration:
Total Days Recumbent:
Total Days in Hospital:
Additional Operations:

END-RESULT DATA SHEET

Date of interview Years since operation:
Duration of back symptoms: Duration of lower-extremity symptoms:
Following surgery: Following surgery:
Date returned to work: Occupation:
Changes of occupation (1) Total immobilization:
(2)
(3)

FINAL RECORD

History

Symptoms
Back pain: Location: Severity: Persistent: Recurrent:
Referred pain: Location: Severity: Persistent: Recurrent:
Stiffness: Weakness:
Other joints:
Disability Dates unable to work: (1)
(2)
(3)
Bedridden: Ambulatory:
Treatment
Medication: Effect:
Brace: Effect:
Physical therapy: Effect:
Additional operations:
Remarks:

Physical Examination

Height: Weight:
Posture A-P Curves: Lateral Curves: Trunk List: Pelvic Tilt:
Spasm Location: Severity:
Tenderness Location: Severity:
Percussion pain Local: Radiating:
Mobility Flexion: Pain: Lateral Bend R: Pain:
Extension: Pain: Lateral Bend L: Pain:
Neurological
Reflexes: Knee R: Knee L: Ankle R: Ankle L:
Sensation: Hypaesthesia: Anaesthesia:
Motor: Muscle weakness: Muscle atrophy: Buttock: Thigh: Calf:
Leverage Tests
Remarks:

X-Ray Findings

Candidates for interviews were chosen as follows: The files of the institutions yielded the names of patients with disc operations and only those falling into the age qualification and time limits were accepted. The records were withdrawn and abstracted and those indicating obvious skeletal involvements, such as spondylolisthesis and fractures, were discarded. In one institution where the number of cases was so great that its complete usage would have led to an imbalance, a sample consisting of every other case was used. In a total of 1,826 case records examined, only 929 were found to meet the requirements and, since eleven patients were found to have died, only 918 became acceptable. To all of these patients letters were sent appealing to their humanitarian sentiments to help us in this study by their personal appearance. Two hundred and thirty-five letters were returned marked "unknown", and 187 of the unreturned letters brought no response, so that only 496 patients were known to have been reached. Of these, 374 (75.4 per cent.)

TABLE I

Institution	Charts Reviewed	Eligible Patients	Known to be Deceased	Possible Candidates
Johns Hopkins Hospital Staff *	643	335	4	331
University of Pennsylvania Hospital	96	63	—	63
Hospital for Joint Diseases	39	24	—	24
Hospital for Special Surgery	110	48	—	48
Massachusetts General Hospital **	749	353	7	346
New York Orthopaedic Hospital	189	106	—	106
Total	1,826	929	11	918

* In The Johns Hopkins Hospital and near-by hospitals.

** Of our records on patients of the Massachusetts General Hospital, 100 were used in the study reported by J. S. Barr: Low-Back and Sciatic Pain. Results of Treatment. J. Bone and Joint Surg., 33-A: 663–649, July 1951.

reported for examination. The 122 patients who did not report did not all give their reasons, but many indicated that the distances were too great, some offered to come if we could pay their fare, and some in belated responses indicated that the letters had been received after the examiner had left their vicinity. Even if we assume that all 683 letters reached their proper destination we find almost 55 per cent., a good response, appeared for the interview.

It is proper to consider the motives of those who returned for the examination, since the figures obtained might be influenced by them. No direct inquiry concerning motive was made of each patient. On the other hand, at the interview it was learned that a large majority came for the sole purpose of helping the study. Some boasted about their results; a few had open compensation interests or were interested in finding possible help for their complaints. However, it is the feeling of the Committee that this is a representative sample.

Patients Examined

A total of 374 patients were interviewed and examined. Of these, 265 were males and 109 were females. The patients came from many walks of life. The banker, the laborer, the secretary, and the housewife were all represented in this group (Table II). In all, at least five years had passed since their operation; in some, ten years.

TABLE II

Type of Occupation

(In 368 Patients)*

	No. of Patients	Per cent.
Patients doing heavy physical labor	125	34
Patients whose work is not usually physically laborious	103	28
Patients with sedentary occupations	77	21
Housewives	63	17

* The occupations of six patients were not listed.

TABLE III

OPERATIONS

	No. of Patients		
Group A: Disc Excision (256 patients)			
Disc excision only		211	
Disc excision with later re-operation for disc	25		
Disc excision with two re-operations for disc	2		
Disc excision with subsequent fusion operation	13		
Disc excision with 2 subsequent fusion operations	1		
Disc excision with 3 subsequent fusion operations	1		
Disc excision with disc re-operation and subsequent fusion	2		
Disc excision with 3 additional disc operations and later fusion	1		
Total (17.58 per cent. of 256)		45	256
Group B: Disc Excision and Spine Fusion (118 Patients)			
Combined operation		100	
Original operation and subsequent re-fusion	10		
Original operation and 2 subsequent re-fusions	5		
Original operation and 3 subsequent re-fusions	1		
Original operation, re-operation on disc, and later re-fusion	1		
Original operation, 2 disc re-operations, and later re-fusions	1		
Total (15.25 per cent. of 118)		18	118
Total number of cases			374

TABLE IV

DAYS SPENT IN HOSPITAL

	Patients with Disc Excision	Patients with Disc Excision and Fusion
Total number of patients	256	118
Patients on whom data not available	7	10
Number of patients	249	108
Total number of days	3,734	6,241
Average number of days per patient	15	58

OPERATIONS

The 374 patients may be divided into two groups, in accordance with their original operations: Group A, those with simple disc excisions, and Group B, those with the combined operation of disc excision and spine fusion. Group A consists of 256 patients, while Group B includes 118 patients. A number of the patients required subsequent operations: forty-five (17.58 per cent.) in Group A and eighteen (15.25 per cent.) in Group B. Some patients were not relieved by the second operation and were later subjected to at least one or more operations (Table III).

DAYS IN HOSPITAL

It is of interest to compare the time loss necessitated by the operative procedures in the two groups. This should include the days spent in the hospital, as well as the period of recovery before the patient could return to his work. The first of these could be obtained from the hospital record and is listed in Table IV. It will be noted that the average hospital stay in Group A, those with disc excision alone, was fifteen days. For Group B, patients with the combined operation, the average was fifty-eight days. The total period

TABLE V

COMPLICATIONS

(Excluding Neurological Complaints)

Complication	Disc Excision		Disc Excision and Fusion	
	No. of Patients	Per cent. of Group	No. of Patients	Per cent. of Group
Shock	1	0.39	3	2.54
Infection	12	4.7	6	5.09
Phlebothrombosis	1	0.39	3	2.54

TABLE VI

RESIDUAL SYMPTOMS

Symptoms	Disc Excision		Disc Excision with Fusion	
	No. of Patients	Per cent. of Group	No. of Patients	Per cent. of Group
Backache only	55	21.5	19	16.1
Backache with pains in lower extremities	84	32.8	35	29.7
Pains in lower extremities only	35	13.7	16	13.56

of convalescence could not be determined with accuracy because many of the patients did not remember; or they did light work at first and gradually increased their activities. In general, the patients with fusions were expected to observe much longer periods of convalescence.

COMPLICATIONS

There were complications in both series of cases. Neurological complications resulting from technical difficulties common to both groups, namely, exposure of the disc and disc enucleation, may be considered unimportant in a comparative study. On the other hand, complications attributable to differences in the magnitude of the operation, the time involved, and the postoperative care are significant. It was found that operative shock and phlebothrombosis occurred more frequently in Group B, but the figures are so small that no great significance can be applied to them (Table V).

RESIDUAL SYMPTOMS

In the combined operation the spine fusion has been offered as a means of correcting the skeletal weakness left by excision of the disc. It is believed by some that the incongruity of the joint from which the disc tissue has been removed will lead to backache, which can be avoided if movement in this joint is eliminated. It is therefore of interest to note the residual symptoms in both groups of cases. We find that backache is a persistent symptom in 139 of the 256 patients with simple disc excision, that is, 54.3 per cent. We do, however, also find this symptom remaining in fifty-four of the 118 patients whose spines had had the fusion operation (45.7 per cent.). Residual symptoms in the lower extremities were found in 46.5 per cent. of Group A, and 43.3 per cent. of Group B (Table VI). Since it is not known how many of the fusion operations were successful in solidly combining the vertebrae, these figures do not serve as an indictment against true spine fusion. It is, however, noteworthy that in the patients with fusion operations there were fewer residual backaches.

TABLE VII

CRITERIA FOR EVALUATING END RESULTS

Excellent: Freedom from symptoms and disabilities.

Very Good: As in "Excellent", except that sensory loss, atrophy, and reflex loss are noted.

Good: Original symptoms cleared up. No recurrences, deformities, or disabilities. Weakness in back (guarding, stiffness, need for support). Mild neurological residua (occasional leg cramps, sensory loss, atrophy).

Fair: Original acute disability cleared up. Recurrences with disability. Painful weak back, necessitating work of lower physical order. Disturbing leg symptoms. Positive leverage tests.

Poor: Symptoms and signs not relieved.

TABLE VIII

END RESULTS

Result	No. of Patients		Per cent. of Group	
Group A: Disc Excision (256 patients)				
Excellent	6		2.34 per cent.	
Very good	33		12.9 per cent.	
Good	114		44.56 per cent.	
Satisfactory		153		59.80
Fair	47		18.38 per cent.	
Poor	11		4.30 per cent.	
Re-operation	45		17.58 per cent.	
Unsatisfactory		103		40.26
Total		256	100.06 per cent.	100.06
Group B: Disc Excision and Fusion (118 patients)				
Excellent	7		5.92 per cent.	
Very good	30		25.42 per cent.	
Good	45		38.13 per cent.	
Satisfactory		82		69.47
Fair	16		13.56 per cent.	
Poor	2		1.69 per cent.	
Re-operation	18		15.25 per cent.	
Unsatisfactory		36		30.50
Total		118	99.97 per cent.	99.97
Total of both groups	374	374		

EVALUATION OF END RESULTS

The evaluation of the end result in any given patient cannot be made in terms of absolute figures. A number of factors had to be weighed, including the postoperative history, the active complaints, and the physical examination. It was quite evident that the patient's own estimate of his condition could not be accepted as valid. Many of those most enthusiastic about their recovery showed obvious marked disability. Others with minor objective findings complained bitterly. On the other hand, the purely objective findings on physical examination likewise did not tell the entire story. Instead, it was found that the most satisfactory evaluation could be reached by considering the patient's

complaints together with the history of postoperative disabilities and the physical findings. Emphasis was laid on the return of the individual to his normal physical activities and on his freedom from disabling recurrences. Thus, the patient without any residua was considered to have an *excellent* result, while a patient who was not relieved of his symptoms and disabilities was considered to have a *poor* result. Those whose findings were between these two extremes were listed as having *very good*, *good*, or *fair* results. Generally speaking, the patient who could carry on his normal work without periods of disability was believed to have a satisfactory result (that is, *very good*, *good*, and *excellent*), while the patient whose capacity for normal work was impaired or was interrupted by disabling episodes was considered to have an unsatisfactory result and was evaluated as *fair* or *poor*. If the condition was such that the patient required another operation, he was assumed to have had an unsatisfactory result and was listed under "re-operation". Table VII lists the factors used for classification. The same criteria were used for all of the patients without reference to their treatment. The nature of the operation was not known to the evaluator while the ratings were being made. It is therefore believed that, whether the standards have been set high or low, the comparisons are valid.

Of 256 patients treated by disc excision alone 153, or 59.8 per cent., were considered to have satisfactory results, while 103, or 40.2 per cent., had unsatisfactory results. Of the 118 patients treated by excision and fusion, eighty-two, or 69.5 per cent., had satisfactory results and thirty-six, or 30.5 per cent., had unsatisfactory results (Table VIII).

In other words, the number of satisfactory results from combining excision with fusion was almost 10 per cent. greater. The best results, that is, few residual difficulties or none, were found twice as frequently in the patients whose spines had been fused, 31.34 per cent. as compared to 15.24 per cent. in those without fusion. Relatively the number of cases requiring further operation is almost the same in the two groups. It is obvious that, although the figures favor the combined operation, the difference is not spectacular, and on a statistical basis is of borderline significance. To quote our biostatistical consultant: "The difference is not large enough to permit us to say with a high degree of certainty that the combined operation would produce consistently better results in the long run".

Discussion and Conclusions

From the material analyzed in this study it appears that, if a hundred patients with herniated nucleus pulposus are subjected to disc excision, one may expect sixty of them to obtain long-term results which are satisfactory. If the same hundred patients should have spine fusions in addition to the disc excisions, the results will be satisfactory in seventy of them. Sixty of these patients would not have needed the fusion operation, and of the forty whose results are unsatisfactory only ten could have expected sufficient improvement to make them satisfactory. Furthermore, the fusion procedure is an added operation, and we have no reason to believe that its effectiveness is greater if it is done at the time of the disc excision than if it is performed at a later date as a second-stage operation. We are therefore led to the conclusion that, when surgical intervention is necessary for simple cases of herniated nucleus pulposus, the operation of choice is disc excision only. Spine fusion can be performed at a later date in those patients whose poor results warrant additional surgery.

Recognition is given to the fact that technical improvements in the operative procedures may be expected. Such improvements may lead to results which differ from those found in this study and will justify a re-evaluation after a lapse of years.

A FEMORAL-HEAD PROSTHESIS FOR THE HIP JOINT

Four Years' Experience and the Results *

BY EARL D. McBRIDE, M.D., OKLAHOMA CITY, OKLAHOMA

From the McBride Clinic, Oklahoma City

The recent appearance of variously designed femoral-head prostheses and glowing early reports of success promise greater satisfaction in hip-joint reconstructions. Time alone will prove the ultimate dependability of the various mechanical designs.

The author first inserted his so-called "door-knob" hip prosthesis in 1948 and presented an exhibit at the Meeting of The American Academy of Orthopaedic Surgeons in 1950. Two particular features had seemed to be responsible for its success: a single-unit construction, and intramedullary anchorage. Hopeless non-union of femoral-neck fractures provided the motive for devising such a prosthesis. Its use thus far has been exclusively in this type of case. It was received with much interest but with much skepticism.

The case of a woman, sixty-five years old, was presented in person; she had undergone the operation six months previously. Even though she had essentially a full range of motion, no pain, and was able to walk on the streets without support, there was a great variety of assertions such as: "It just won't work"; "Too much metal"; "The acetabulum won't stand up"; "There will be pressure necrosis"; "It will work loose". Now that this type of prosthesis has proved surprisingly satisfactory over a period of four years, there are certain facts that should be stressed in relation to the results obtained.

The Spherical Head

It is quite likely that the use of the spherical-head replacement in hip reconstruction would have been developed further following Moore and Bohlman's report of a successful result in 1940 had their design of anchorage been more practical. Their success was due chiefly to the advantages of a non-electrolytic metal, which Delbet, Hey Groves, Robineau, and others did not have when they attempted to replace articular structures by a prosthesis. Bohlman also designed a femoral-head prosthesis with pin fixation through the neck and trochanter, but did not publish his experiences because he preferred to observe whether or not transmission of weight through the trochanter would eventually produce rarefaction, looseness, and extrusion.

Durability

Permanence of the prosthesis will depend on durability of the material, tolerance of the acetabulum and stress-bearing bone, and stability of anchorage.

Steel and Vitallium have long been used with dependability. Plastic is promising because of its resilience, but has yet to be proved for durability.

The Vitallium-cup arthroplasty of Smith-Petersen has very well proved the tolerance of the acetabulum and capsular tissues to the wearing forces of smoothly molded metal in motion. It must be observed, however, that the spherical prosthetic head permits almost normal muscle function and a much greater excursion of motion than does a cup, so that the acetabulum is subject to a wearing action approaching that of the normal femoral head. Others have reported a disturbing "squeak" in the hip, which is suggestive of the extent of mechanical friction.

The lack of a dependable method of anchorage of the prosthesis to the femur has

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 29, 1952.

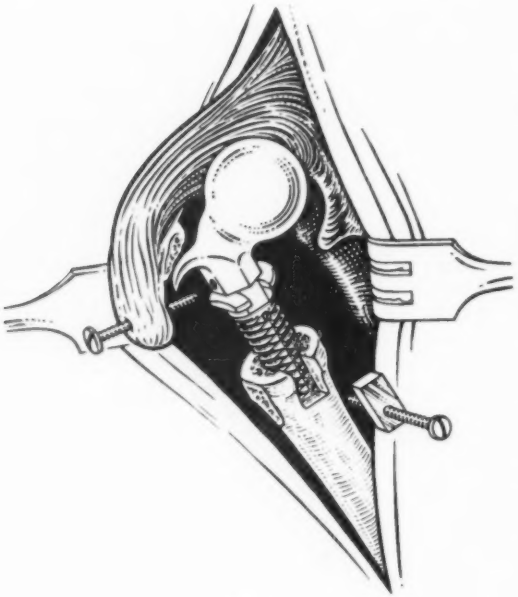

FIG. 1

The door-knob prosthesis is screwed into the medullary canal.

been the principal deterring factor to most surgeons. There is a fear that with time, because of the constant stresses of metal or plastics on the bone tissues, the prosthesis will gradually become unstable. The axial, shearing, and bending forces on the greater trochanter and neck of the femur are exceedingly powerful.[6] Variations in the quality of the bone texture and strength influence the reliability of fixation of the prosthesis to the trochanter. In the aged, the neck and trochanter are likely to be very atrophic. In the younger person the bone is more substantial, but stability of anchorage must withstand more energetic activity over a much longer period of time.

MECHANICAL PRINCIPLES

It is clear, therefore, that there are three mechanical essentials in the design of a hip-joint prosthesis: (1) The mechanical integrity of the prosthesis must be assured; (2) the method of anchorage must ensure permanent stability; and (3) bone deterioration occurring in the course of time must not alter the stability of fixation.

Single-Unit Design

The mechanical integrity of the prosthesis can be assured only if it is a single unit in which no essential components can become loose, disintegrate, come apart, or wear out. The author's prosthesis is a single unit of Vitallium, molded in one piece, or a steel unit, lathed from a three-inch cylindrical bar. The author's preliminary experiments were with an assembled unit, composed of a spherical head screwed into a shaft, the screw extending through the trochanter and neck, and plated to the shaft with screw fixation. Because of the complications of assembly and the leverage on screws in the cortical shaft of the femur, which was often atrophic, this design was abandoned.

Intramedullary Anchorage

Intramedullary anchorage of the prosthesis was chosen because it seemed the more permanently reliable method for guarding against looseness resulting from bone deterioration. The basis of this reasoning is, first, that experience with intramedullary pins in fractures had proved the tolerance of the bone shaft to the large metal bar. Hudack's replacement experiments with the flanged nail seated in the medullary canal were also encouraging. Second, the threaded stem, if accurately and firmly seated, offered all the advantages of a bone screw. Third, the prosthesis was designed chiefly for older persons with ununited fractures of the femoral neck and aseptic necrosis. Rarefaction of the femoral neck and trochanter, commonly encountered, would prohibit dependable anchorage of a prosthesis within these structures. This was especially true in cases in which a cavity existed from the perforation of some previous fixation. Furthermore, the experience that

pins and screws can create rarefaction and migrate when loosened in a bone shaft led the author to guard against a similar occurrence in the rarefied femoral neck and trochanter. Finally, in many of these cases there was not enough of the femoral neck left on the trochanter to support anchorage of a prosthesis efficiently by any method other than the intramedullar.

"DOOR-KNOB" HIP PROSTHESIS

Briefly described, the author's design of a hip-joint prosthesis consists of a single unit, made of Vitallium or No. 317 stainless steel, with a spherical head, a neck, and a threaded intramedullary stem, about six and one-half inches long.[7] A weight-bearing rim extends from the upper edge of the threaded stem and renders axial support to the prosthesis on the upper end of the femoral shaft. This brings the femur more nearly into the perpendicular line of equilibrium and lessens the torque at the distal end of the intramedullary stem on the femoral shaft. The head is made in three sizes: one and three-quarters inches in diameter, for the average female, five foot three inches in height; one and thirteen-sixteenths of an inch in diameter for a male or a larger female; and one and seven-eights of an inch in diameter for the larger male.

Once it had been decided to use the medullary canal for anchorage, it became necessary to determine the more practical method of permanently stabilizing the prosthesis against rotation and bending forces. Driving the steel stem into the intramedullary canal might fracture the shaft; there was also the danger that the stem might work loose. Screws placed in the cortex might produce a fatigue fracture of the shaft. The more mechanically sound method seemed that of screwing the stem firmly into the medullary canal. The

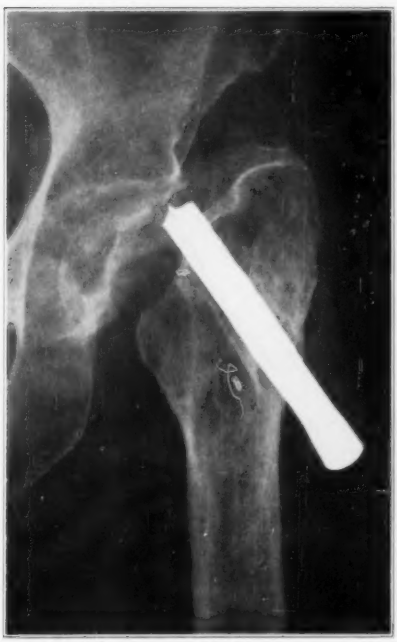

FIG. 2-A

FIG. 2-B

Fig. 2-A: Mrs. W. B. P. (Case 10). Roentgenogram made before operation, showing non-union.
Fig. 2-B: Roentgenogram made fourteen months after introduction of the door-knob prosthesis.

TABLE I
ANALYSIS OF RESULTS

Case No.	Age	Period of Follow-up (*Months*)	Walking with Crutches	Walking without Crutches	Pain, (More than Mild Soreness)	Good Free Motion	Complications
1. Mrs. I.	70	47	Yes		No	Yes	Femur remains fragile. Carcinoma of bladder
2. A.H.D.	58	42		Yes	No	Yes	None
3. E.L.M.	65	40		Yes	No	Yes	None
4. M.E.	81	41	No	No	No	Yes	Senile psychosis
5. A.E.	68	25		Yes	No	Yes	None
6. M.M.	77	24		Yes	No	Yes	None
7. B.A.D.	46	26		Yes	Yes	Yes	Painful, stiff knee
8. R.L.	73	23	Yes		No	Yes	Loss of equilibrium
9. G.M.	72	27		Yes	No	Yes	None
10. W.B.P.	81	23	Yes		No	Yes	None
11. F.P.	84	23		Yes	No	Yes	None
12. L.H.	50	19		Yes	Yes	Yes	Acetabulum partly destroyed by surgical fusion
13. T.H.R.	74	14		Yes	No	Yes	None
14. C.D.C.	76	15		Yes	No	Yes	None
15. E.A.	72	20		Yes	No	Yes	None
16. R.S.T.	73	15	Yes		No	Yes	None
17. E.D.L.	63	19		Yes	No	Yes	None
18. C.K.	38	15		Yes	Yes	Yes	Osteo-arthritis, severe
19. P.W.J.	71	Died (Circulatory failure)					
20. C.E.R.	50	20		Yes	No	Yes	Defective prosthesis; replaced
21. J.G.	67	20	Yes		No	No	Rheumatoid arthritis
22. G.F.	46	17	Yes		Yes	No	Required revision of the acetabulum

anchorage stem was tapered to fit the medullary canal and provided with self-cutting coarse threads, each of which would carry weight and act as a stabilizing support. Rotation was prevented by a metal block and a set screw, fitted into a notch in the femur.

OSTEOTOMY OF THE TROCHANTER

Some have questioned the necessity of osteotomy and retraction of the trochanter and have expressed apprehension toward such a procedure. This, however, facilitates screwing of the threaded stem into the medullary canal. The first essential to permanent tolerance of bone to metal screws is absolute stability. This can be assured only by accurate fitting of the threads in the bone. Assurance of stability of the threaded stem of the prosthesis therefore justifies osteotomy of the trochanter. Nothing is lost except for the proximal portion of the neck. The replaced trochanter is fitted to the prosthesis and overlapped on the bone shaft to re-unite with it. Should removal of the prosthesis become imperative, there would be about as much trochanteric bone substance as one usually finds in arthrodesing an old non-union of the femoral neck.

TECHNIQUE

The prosthesis is inserted by the anterolateral or posterior approach. Earlier ambulation is permitted with the posterior incision, because the stronger anterior capsular support is not subjected to trauma. The trochanter is separated from the shaft by an osteotomy at the level of the upper margin of the lesser trochanter. The glutaeus medius is left intact as the trochanter is retracted. The limb is rotated and abducted so that the cut end of the femur protrudes from the wound. A threader is introduced into the medullary canal and screwed down to the proper depth. Various sizes of prostheses are tried in the acetabulum to determine the best fit. When the prosthesis has been selected, the stem is screwed into the medullary canal until the weight-bearing rim fits firmly on the cut end of the femur. Further adjustment in rotation brings the head and neck into the proper forward angle of about 25 degrees. The prosthesis is then stabilized by cutting a notch in the upper end of the femur into which the metal block and screw are fitted. The trochanter is shaped to fit the curved metal neck. The latter is pressed on a hook on the trochanter and is bolted in a position that permits one-half inch of overlapping with the shaft. With reduction of the head of the prosthesis, the wound is ready to close. In cases of non-union, the capsule is preserved and the acetabulum is not reamed out. Efforts to restore length should not create severe stress on the acetabulum by the prosthesis. If tension is too severe and if there is a tendency to dislocation, the adductors should be tenotomized. Traction in bed with the limb in abduction and neutral rotation is maintained for about ten days. Walking with crutches is permitted in three weeks and weight-bearing without crutches in six to eight weeks, depending on the bone texture and the general condition of the patient.

ADVANTAGES

The advantages of the door-knob hip prosthesis may be summed up as follows:

1. Surgical introduction does not require time-consuming details of assembling. The only special instruments are a wrench and a threader.

2. Intramedullary fixation in the femur affords stability and a minimum of leverage against cortical bone.

3. A normal range of hip motion is provided by the spherical head without impingement, pain, or danger of dislocation.

4. All muscle-propelling forces are retained by re-attachment of the trochanter to the shaft.

5. Shortening of the extremity can be eliminated when contractures are not severe.

6. Stability and weight-bearing support is dependable.

7. Vitallium, or No. 317 stainless steel, of which the prosthesis is made, is dependably non-electrolytic.

8. The patient may begin walking on crutches within three weeks without fear of disturbing the fixation of the prosthesis.

RESULTS

So far, the prosthesis has been used in twenty-two patients (Table I).

In order to judge the results in the replacement of the femoral head by a prosthesis, the cases should be divided into three groups:

1. Those in which there is good bone texture in the neck and trochanter;
2. Those in which there is decreased bone density and absorption;
3. Those in which there is a diseased or defective acetabulum.

The first group includes ununited fractures of the femoral neck in younger persons and such conditions as malum coxae senilis and traumatic arthritis.

The second group includes non-union and aseptic necrosis of the femoral neck, fractures in the aged, and tumors with rarefaction of the neck or trochanter.

The third group includes rheumatoid arthritis, failure of fusion of the hip joint, and comminuted fractures of the acetabulum.

It is quite possible to select the type of prosthesis which suits the case. If the bone in the neck and trochanter is found to be of sound texture, it will no doubt provide dependable stability for any type of prosthesis. If the neck and trochanter are atrophic, or if there is little or no neck, the author's prosthesis which provides intramedullary anchorage seems more mechanically reliable.

Ability to walk

The criterion of success and satisfaction has not been that of striving for locomotion with perfection. Since the cases selected up to the present time are all those of non-union of the femoral neck, there are many obstacles to the patient's ability to walk; some have stiff and painful knees or ankles, and some have lost their equilibrium so that it is not safe to permit them to walk.

Pain

Actually, the greatest advantage to the patient seems to be the elimination of severe pain. Natural, easy motion is also a great satisfaction. All patients have admitted some mild soreness, but only four are unable to walk with satisfaction because of pain.

All four are in the younger age group, forty-six to fifty, and expect more than the reconstructed hip will withstand:

Mrs. G. F., Case 22, had osteomyelitis resulting from three previous operations which was probably responsible for the pain. Her acetabulum has been revised once since the insertion of the prosthesis, but disabling pain still exists. She is relieved by immobilization.

L. H., Case 12, had a stiffened knee, as well as a hip fusion preceding the insertion of the prosthesis, so that the acetabulum required extensive reaming.

B. A. D., Case 7, a very active oil-field executive, on two occasions was immobilized for many weeks in a plaster spica. He now insists that his pain is in his knee, but undoubtedly the hip is partly responsible.

C. K., Case 18, has a liability suit still unsettled. Marked overgrowth of callus about the acetabulum indicates that there may be cause for complaint of pain.

Bone Deterioration

It was originally feared that the large threaded intramedullary stem would erode

the bone tissue of the cortex and become loose. This has been true in one case (Mrs. I., Case 1). (The diagnosis in this case was carcinoma of the bladder.) Atrophy from disuse was severe. There has been no callus repair about the trochanter, which remains ununited. Even so, the patient for three years has walked quite well with one crutch or a stick for support. Recently, because of fear of fracture, she has been ordered to use crutches altogether.

Deterioration of the Acetabulum

There has been no evidence of a migrating acetabulum or other deterioration.

Dislocation

There have been no postoperative dislocations. In one case there was x-ray evidence of unsatisfactory seating of the head of the prosthesis in the acetabulum.

Operative Complications

There have been no serious complications or disappointments in the operation, or in the progress of the patients.

Hip Motion and Shortening

All patients have a noticeable limp; some walk extremely well, however, and even dance. This limp is not due to shortening. It is due to weakness of the abductors, which resulted from sacrificing the normal angle of the neck of the femur. Internal rotation is sometimes greatly limited, but external rotation is usually normal. Flexion averages about 70 degrees in most cases, but the ability to raise the extended extremity from the table is generally lacking. Abduction and adduction have a normal range in all but four cases.

Defective Prosthesis

In one case, Mrs. C. E. R., Case 20, the prosthesis broke at the base of the neck because the steel was defective. A new one was substituted, and the patient is walking almost without a limp. Recent roentgenograms indicate that the threaded stem is not as firm in the bone as was the first prosthesis.

CONCLUSIONS

The spherical-head prosthesis offers a new type of hip reconstruction. Intramedullary anchorage by a threaded stem, as provided by the door-knob type of prosthesis devised by the author, has proved generally satisfactory in twenty-two cases. Complications have been of minor consequence. This type of prosthesis is especially dependable when the major portion of the femoral neck is absent and when there is lack of good bone texture in the trochanter.

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BONE-SUTURE GUIDE

A NEW INSTRUMENT FOR SUTURING SOFT TISSUE TO BONE

BY DAVID GOLDBERG, M.D., SPRINGFIELD, MASSACHUSETTS

Occasionally it becomes necessary to suture a ligament, tendon, or similar soft-tissue structure directly to the adjacent bone. If the bone is spongy in character, the surgeon may be able to force a stout cutting needle or a sharp awl through it without too much difficulty. On the other hand, if the adjacent bone is of the consistency of cortical bone, it becomes necessary that a channel be formed with a drill.

With the conventional drill it is often necessary that considerable stripping of soft tissues be done before this channel can be made. The right-angled dental drill may enable the surgeon to work in a smaller wound, but it becomes necessary that he make two holes in the cortex at an angle, trust that they meet beneath the cortex, and hope that he is able to thread a curved needle through both holes without breaking the needle. He invariably discovers that a curved needle will not penetrate V-shaped holes.

FIG. 1

FIG. 2

Fig. 1: Photograph of the instrument, showing the handle, the plate at one end, the guide hole, and the pivot point. A drill point is inserted into the guide hole. A No. 8 steel crochet hook is also shown.

Fig. 2: The guide is pivoted on its point and another drill hole is made. Both holes must meet below the surface.

FIG. 3

FIG. 4

Fig. 3: A loop of catgut is inserted into one hole. A No. 8 steel crochet hook is inserted into the other hole; the catgut is easily pulled through.

Fig. 4: Photograph shows the catgut pulled through both holes. Silk, linen, cotton, or wire may be tied to catgut and pulled through.

In meeting these difficulties in the past, the author has developed a guide which enables the surgeon to place quickly and accurately a suture through any type of bone, even though the exposure be confining.

The instrument (Fig. 1) is made of steel and consists of a handle with a small plate at one end in which a guide hole has been made at an angle. This angle is so constructed that when a drill is inserted, it will strike a central point approximately one-half inch beneath the surface. The hole in the plate is made large enough to admit the usual drill point (No. 36) which is commonly used to make holes for bone screws. Below the center of this plate is a sharp point which is driven into the bone and is used as a pivot. A single steel crochet hook (No. 8) which may be purchased in any ten-cent store, completes the armamentarium.

PROCEDURE

The sharp point is driven into the bone. With an electric drill, a No. 36 drill point is directed through the guide hole in the plate. A hole approximately one-half inch in depth is made so that the cortex may be penetrated. The drill point is withdrawn, the handle of the guide is pivoted on its point to any part of a complete revolution, and another half-inch hole is made. Thus both drill holes will meet about one-half inch beneath the surface. It is essential that the handle of the guide be held perpendicular to the cortex while the holes are being made.

A piece of any heavy catgut is then folded and the double end is inserted into one hole. This is easily pulled out by means of the crochet hook inserted into the other hole. If silk or wire is desired, it can be tied to the catgut and pulled through both holes.

If smaller holes are desired — for instance, when one is suturing to metacarpals or metatarsals — then another plate can be applied which has a smaller guide hole. A smaller crochet hook can be purchased at any dime store.

The author advises the use of an electric drill in order to avoid the tendency of breaking the drill point as the handle shakes back and forth when the operator turns the conventional hand drill.

News Notes

The Twentieth Annual Meeting of **The American Academy of Orthopaedic Surgeons** will be held at the Palmer House, Chicago, Illinois, on January 24 to 29, 1953.

The Eighth Annual Meeting of the **American Society for Surgery of the Hand** will be held January 23, 1953, at the Palmer House, Chicago, Illinois. Registration of guests from 8 A.M. to 9 A.M. Formal program from 9 A.M. to 5 P.M. Residents, interns, and members of the Armed Forces will be admitted free upon presentation of credentials.

The American Board of Orthopaedic Surgery announces that the deadline for the receipt of applications for the 1953 Part I examinations is November 30, 1952.

The Fifty-ninth Annual Meeting of the **Association of Military Surgeons** of the Department of Defense will be held at the Statler Hotel in Washington, D. C., November 17 to 19 under the presidency of Major General Harry G. Armstrong, Surgeon General of the Air Force. Reserve credit points may be earned by Medical Service Reserve Officers for attendance at the daily sessions.

The following institutions and the respective Chiefs of Service wish to announce that applications are now being received for an approved three-year training program in adult and children's orthopaedic surgery, fractures, and basic sciences.

Boston City Hospital, Boston, Massachusetts
Russell F. Sullivan, M. D.
Massachusetts Hospital School, Canton, Massachusetts
Paul L. Norton, M. D.
Shriners Hospital, Springfield, Massachusetts
Garry de N. Hough, Jr., M. D.
The Lahey Clinic, Boston, Massachusetts
G. Edmund Haggart, M. D.

Inquiries should be directed to Dr. G. Edmund Haggart, The Lahey Clinic, 605 Commonwealth Avenue, Boston 15, Massachusetts.

The alumni of the **Hospital for Joint Diseases** will hold their Annual Conference at the Hospital on October 30 and 31 and November 1, 1952. The day and evening of October 30 will be given over entirely to Dr. Joseph Trueta, Nuffield Professor of Orthopaedic Surgery, of Oxford, England. On that day, he will devote one session to a follow-up clinic and panel discussion on cases of acute and chronic pyogenic osteomyelitis, another session to a talk on "Acute Hematogenous Osteomyelitis, Its Pathology and Treatment", and the evening session to the annual Walter M. Brickner Lecture, for which he will take as his subject "The Influence of the Blood Supply in Controlling Bone Growth".

On the morning of October 31, Dr. Anthony F. DePalma, Professor of Orthopaedic Surgery of the Jefferson Medical College, Philadelphia, will conduct a panel discussion on the subject of the shoulder-neck pain syndrome. Another feature of the conference will be a panel discussion of the present-day status of work in the field of the autonomic nervous system and a panel discussion on myelography.

The Annual Meeting of the **North Pacific Orthopedic Society** was held in Seattle, Washington, on May 16 and 17, 1952. The scientific programs were held at the Swedish Hospital on Friday and at the Children's Orthopaedic Hospital on Saturday. The program follows:

Bilateral Recurrent Dislocation of Shoulders. Surgical Repair: Dr. Harry Emmel.
Conservative Surgical Management of Foot Lesions in the Diabetic Patient: Dr. James Miller.
Arthrodesis of the Symphysis Pubis. Three Cases: Dr. Edward LeCocq.
Neurofibroma of Peripheral Nerves: Dr. George W. Cottrell.
Synovioma. Case Report: Dr. L. Stanley Sell.
Suspension Test for Spondylolisthesis: Dr. E. F. S. Chambers.

Plantar Interdigital Neuroma at an Unusual Location: Dr. Paul Ruuska.
Patellectomy with Fascia Lata Replacement: Dr. Irving Tuell.
Results of Surgical Restitution of the Hip by the Vertical-Coaxial Prosthesis: Dr. Roger Anderson.
Acrylic Prosthesis for Substitution of the Proximal Humerus: Dr. Joe B. Davis.
Cup Arthroplasty and Allied Reconstructive Surgery of the Hip. Case Studies: Dr. John LeCocq.
Biceps Cineplasty. Present Techniques and Terminal Devices with Case Presentations: Dr. Robert Mazet (by invitation).
Recent Surgical Trends in the Cerebrospastic Upper Extremity: Dr. William Duncan.
A New Technique and Apparatus for Determining Torsion of the Femur. With a Report of the Torsion of 810 Femora: Col. Knox Dunlap (by invitation).
Opponens Paralysis. Surgical End Result in Fourteen Cases: Dr. Ernest Burgess.
Congenital Familial Interarticular Menisci in Fingers. Case Reports: Dr. Forrest Flashman.
Certain Non-Infectious Joint Diseases. Case Reports: Dr. Ira McLemore.
Interesting and Unusual Cases: The Resident Staff.

THE AMERICAN ORTHOPAEDIC ASSOCIATION

Among the members of The American Orthopaedic Association who attended the Joint Meeting of the Orthopaedic Associations of the English-Speaking World, held in London, June 30 to July 4, 1952, many made the trip on the Ile de France. For this group the Transatlantic Orthopaedic Forum was planned by a Program Committee of which Dr. A. R. Shands, Jr., was Chairman. The program was as follows:

First Session, Saturday, June 21, 1952.

Call to Order and Remarks.
Dr. Fremont A. Chandler, President of The American Orthopaedic Association, Chicago, Illinois.
Dysplasia Epiphysealis, Case Reports.
Dr. George J. Garceau, Indianapolis, Indiana.
Case Reports: 1. Fixation of Fresh Subcapital Fracture of the Neck of the Femur;
2. March Fracture of the Neck of the Femur;
3. Late Complication of Hip Prosthesis.
Dr. George O. Eaton, Baltimore, Maryland.
Orthopaedic Reminiscences.
Dr. Arthur Steindler, Iowa City, Iowa.

Second Session, Monday, June 23, 1952.

Transplantation of Tendons through Preformed Sheaths.
Dr. Joseph E. Milgram, Brooklyn, New York.
Case Reports: 1. Unusual Ankle Pathology Following Sprain;
2. Osteoid Osteoma of Fourth Lumbar Vertebra.
Dr. Joseph A. Freiberg, Cincinnati, Ohio.
Unusual Pathology in the Upper Portion of the Tibia in Children, Case Reports:
1. Congenital Dislocation of the Knee;
2. Crushing Fracture;
3. Giant-Cell Tumor.
Dr. W. K. West, Oklahoma City, Oklahoma.
A Report from Washington.
Dr. Paul B. Magnuson, Washington, D. C. and Chicago, Illinois.

Third Session, Tuesday, June 24, 1952.

Sling Procedure for the Correction of Splay Foot, Primus Varus, and Hallux Valgus Deformities (moving-picture film).
Dr. Robert J. Joplin, Boston, Massachusetts.
A Method for Arthrodesing of the Hip Joint.
Case Reports: 1. Osteochondritis Dissecans of the Hip;
2. Hallux Rigidus.
Dr. Don King, San Francisco, California.
Surgery for Complications of Paget's Disease.
Dr. Irvin Stein, Philadelphia, Pennsylvania.
Remarks on Cerebral Palsy.
Dr. Winthrop M. Phelps, Baltimore, Maryland.

Transatlantic Orthopaedic Forum of The American Orthopaedic Association, Ile de France, June 25, 1952.

First Row: (Left to right) Dr. W. M. Phelps, Baltimore, Maryland; Dr. J. R. Moore, Philadelphia, Pennsylvania; Dr. L. S. Lucas, Portland, Oregon; Dr. W. K. West, Oklahoma City, Oklahoma; Dr. F. A. Chandler, Chicago, Illinois; Dr. P. B. Magnuson, Chicago, Illinois; Dr. A. R. Shands, Jr., Wilmington, Delaware.

Second Row: Dr. W. M. Ewing, Louisville, Kentucky; Dr. H. P. Mauck, Richmond, Virginia; Dr. W. E. Grieve, Spokane, Washington; Dr. W. J. Schnute, Chicago, Illinois; Dr. Joseph Buchman, New York, N. Y.; Dr. R. J. Joplin, Boston, Massachusetts; Dr. Arthur Steindler, Iowa City, Iowa.

Third Row: Dr. J. A. Freiberg, Cincinnati, Ohio; Dr. Irvine Flinn, Wilmington, Delaware; Dr. G. O. Eaton, Baltimore, Maryland; Dr. Irvin Stein, Philadelphia, Pennsylvania; Dr. Frank Stinchfield, New York, N. Y.; Dr. Armin Klein, Boston, Massachusetts; Dr. J. E. Milgram, Brooklyn, New York.

Members not present included: Dr. Don King, San Francisco, California; Dr. R. L. Patterson, New York, N. Y.; Dr. G. J. Garceau, Indianapolis, Indiana.

FOURTH SESSION, WEDNESDAY, JUNE 25, 1952.

A Few Remarks on Stabilization Operations of the Knee Joint.
Dr. H. Page Mauck, Richmond, Virginia.
Giant-Cell Tumor of a Cervical Vertebra with Twenty-Year Follow-up: A Case Report.
Dr. W. E. Grieve, Spokane, Washington.
Treatment of Contralateral Hips in Slipped Capital Femoral Epiphysis.
Dr. Armin Klein, Boston, Massachusetts.
Case Reports:
Dr. J. R. Moore, Philadelphia, Pennsylvania.
Dr. A. R. Shands, Jr., Wilmington, Delaware.
Round Table Discussion.

The Program Committee of The American Orthopaedic Association, Dr. Walter P. Blount, Chairman, collaborated with their British colleagues in planning the program for the London Meeting. The sessions of the Meeting in London are reported on page 1002.

Executive sessions of The American Orthopaedic Association were held in London on Tuesday, July 1, and Thursday, July 3. At the Second Executive Session the President for the coming year, Dr. James A. Dickson of Cleveland, Ohio, was inducted into office. The following officers and members of committees were elected:

Officers

President-Elect: A. R. Shands, Jr., M.D., Wilmington, Delaware;
Vice-President: Paul B. Steele, M.D., Pittsburgh, Pennsylvania;
Secretary: George O. Eaton, M.D., Baltimore, Maryland;
Treasurer: H. Page Mauck, M.D., Richmond, Virginia.

Committee Members

Membership Committee: Herman Young, M.D., Rochester, Minnesota;
Program Committee: Lenox D. Baker, M.D., Durham, North Carolina;

Research Committee: Paul C. Colonna, M.D., Philadelphia, Pennsylvania.

Representatives on The American Board of Orthopaedic Surgery

Harold A. Sofield, M.D., Chicago, Illinois;
Edwin F. Cave, M.D., Boston, Massachusetts.

Delegate to the American College of Surgeons

Don King, M.D., San Francisco, California.

The following new members were elected:

Active Members:

Dr. J. Hamilton Allan, Charlottesville, Virginia;
Dr. Clinton L. Compere, Chicago, Illinois;
Dr. Edward T. Evans, Minneapolis, Minnesota;
Dr. K. Armand Fischer, Louisville, Kentucky;
Dr. S. Benjamin Fowler, Nashville, Tennessee;
Dr. J. Neill Garber, Indianapolis, Indiana;
Dr. George Hammond, Boston, Massachusetts;
Dr. Robert A. Knight, Memphis, Tennessee;
Dr. Paul E. McMaster, Los Angeles, California;
Dr. Paul L. Norton, Boston, Massachusetts;
Dr. Carter R. Rowe, Boston, Massachusetts;
Dr. Albert C. Schmidt, Milwaukee, Wisconsin;
Dr. L. Ramsay Straub, New York, N. Y.;
Dr. Milton S. Thompson, San Antonio, Texas;
Dr. Walter A. L. Thompson, New York, N. Y.

Corresponding Member

Dr. Robert Merle d'Aubigné, Paris, France.

The next Annual Meeting of The American Orthopaedic Association will be held at The Homestead, Hot Springs, Virginia, June 28 to July 1, 1953.

CHARLES E. SEVIER

1889–1952

Dr. Charles E. Sevier of Colorado Springs, Colorado, died March 8, 1952.

He was born May 23, 1889, in Brownsville, Tennessee, where both his father and grandfather were practising physicians. Here he received his preliminary education, following which he was graduated from Vanderbilt University in 1912 with the Degree of Bachelor of Science. He received his medical degree at Johns Hopkins in 1916 and completed his medical internship at The Johns Hopkins Hospital the following year.

With the advent of World War I, he served as Captain in the Medical Corps with Base Hospital 22 in France. From 1918 to 1920 he was House Officer in Surgery at the New York Hospital on the Service of the late Dr. Eugene Pool.

Becoming interested in bone and joint diseases, Dr. Sevier spent a year in Switzerland studying in the Rollier Clinic, and on returning to the United States became House Officer at the Hospital for the Ruptured and Crippled, New York City. Following this, he became associated in the practice of orthopaedic surgery with the late Dr. S. Fosdick Jones in Denver, Colorado. After the retirement of Dr. Jones, Dr. Sevier and Dr. Atha Thomas were associated in private practice for many years.

He was made Associate Professor of Orthopaedic Surgery, University of Colorado Medical School, in 1931. Later, due to failing health, he was forced to give up his work in Denver, and during the last few years of his life he made his home in Colorado Springs with his brother, Dr. John A. Sevier.

At the time of his death, Dr. Sevier was a senior member of The American Orthopaedic Association, emeritus member of The American Academy of Orthopaedic Surgeons, and had been certified by The American Board of Orthopaedic Surgery. He was a member of the Nu Sigma Nu, Phi Beta Kappa, and Alpha Omega Alpha fraternities.

In spite of the handicap of continued poor health, he pursued his professional duties with great enthusiasm and interest. His sincere devotion to his work and his ever genial and sympathetic nature endeared Dr. Sevier to patients and friends alike, and he will be keenly missed by all who knew him.

JOINT MEETING OF THE ORTHOPAEDIC ASSOCIATIONS OF THE ENGLISH-SPEAKING WORLD, 1952.

In 1929, a joint meeting of The American and British Orthopaedic Associations was held in London; again, in 1948, these two Associations held their Annual Meetings together—this time in Quebec where they were joined by a newly formed group, The Canadian Orthopaedic Association. This year, from June 30 to July 4, these three Associations again met together—in London—where they were joined by three newly formed groups—The Australian Orthopaedic Association, the New Zealand Orthopaedic Association, and the South African Orthopaedic Association. A large majority of the entire membership of the six national Associations attended. Present also were many distinguished surgeons from countries all over the world, including Argentina, Belgium, Brazil, Denmark, Finland, France, Greece, Italy, the Netherlands, Panama Canal Zone, Philippine Islands, Portugal, Sweden, and Switzerland.

The Meeting was opened by H. M. Queen Elizabeth, the Queen Mother, in an impressive inaugural ceremony held in the Senate House of the University of London on the morning of June 30. Following short addresses of welcome by the Chancellor of the University, the Earl of Athlone, and Sir Reginald Watson-Jones, President of The British Orthopaedic Association, the Queen Mother spoke of the importance to mankind of orthopaedic surgery, of the almost unlimited opportunities for service which lie ahead, and of her delight at being present at a meeting of orthopaedic surgeons from every part of the English-speaking world. The President of each of the visiting Orthopaedic Associations then replied, and each, in turn, was presented by Her Majesty with jewels of office, the gift of The British Orthopaedic Association: for the United States, Dr. Fremont A. Chandler; for Canada, Dr. R. Graham Huckell; for Australia, Mr. Esmond F. West; for New Zealand, Mr. Alexander Gillies; and for South Africa, Mr. G. T. du Toit.

Monday, June 30

The scientific sessions were opened on the afternoon of June 30. Summaries of the papers presented at these sessions follow:

Traumatic Dislocation of the Hip. Mr. E. A. Nicoll[1], reporting on behalf of the Clinical Research Committee of The British Orthopaedic Association, stated that a survey of 144 patients who had been treated for traumatic dislocation of the hip had revealed an incidence of aseptic necrosis of the femoral head of 10 per cent. He warned against confusing necrosis with traumatic arthritis, a mistake which he felt was responsible for wide variations in the incidence sometimes reported from other sources.

Roentgenographic evidence of necrosis always preceded symptoms and, when necrosis was present, it always became manifest within two years of the time of injury. Traumatic arthritis, on the other hand, developed more slowly and was relatively benign.

That necrosis of the femoral head occurred more often in children than in adults following dislocation was due to the absence of blood supply across the epiphyseal cartilaginous plate when the head had been deprived of the retinacular supply at the time of the injury. In over half of the patients in whom necrosis had been observed, there had been delay in reduction or repeated attempts at reduction; he concluded that early recognition and gentleness were essential to proper treatment. Another important factor seemed to be the avoidance of early weight-bearing; necrosis had occurred in 20 per cent. of patients who had been permitted weight-bearing within the first month as opposed to 7.5 per cent. in those who had been restrained. It was significant, however, that he felt even prolonged withholding of weight-bearing could not be expected to result in an intact head once there was necrosis, for creeping substitution had not proved sufficient for complete restoration; inevitably there had occured degeneration of articular cartilage and collapse of the head. On the other hand, to withhold weight-bearing for more than eight weeks was not justified in view of the relatively low incidence of necrosis. Routine roentgenographic check four times a year for two years was held to be essential to proper follow-up. Functionally, results had not been found to be proportional to the changes resulting from necrosis—only six of the fifteen patients with dead heads had needed surgery.

End-Result Study of Dislocation and Fracture-Dislocation of the Hip. Dr. J. S. Speed [2] and Dr. Marcus J. Stewart [3], reporting the results of their analysis of 128 cases of dislocation and fracture-dislocation of the hip, felt that necrosis occurred regardless of age or the time of weight-bearing; the extent of the damage at the time of injury and the time lost between injury and reduction were the important factors. So serious was delay in its effect on the ultimate result that reduction was, in fact, an emergency of the first importance. Because they had found the time of onset of necrosis to be the same—seventeen months—regardless of whether the reduction had been by the open or closed method, antecedent factors were apparently responsible. Clinical evidence of sciatic-nerve injury in conjunction with sizable displaced fragments demonstrable roentgenographically was clear indication for exploration of the nerve.

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Discussing the two foregoing papers, DR. PAUL B. MAGNUSON [4] emphasized that, clinically, functional results could be in inverse proportion to the changes present roentgenographically. MR. JAMES PATRICK [5] was of the opinion that differentiation between aseptic necrosis and traumatic arthritis was often quite clear although overlooked; the former might suddenly supervene as collapse of the head in spite of apparently negative roentgenographic evidence over many months. MR. J. M. EDELSTEIN [6] also emphasized that the extent of the initial injury was often not apparent and that prognosis must always be guarded. He pointed out the possibility of using internal prostheses in cases of femoral-head collapse. DR. G. L. INGE [7] stressed the importance of early reduction by presenting case histories. He had found it a wise precaution in all possible dashboard accidents to have roentgenograms of the hips made. MR. K. H. PRIDIE [8] felt that while massive capital collapse could be easily identified, lesser degrees of necrosis and direct traumatic changes were often indistinguishable, minor foci of necrosis producing degeneration of cartilage and spreading hypertrophic changes typical of so-called traumatic arthritis.

In closing, MR. NICOLL acknowledged that creeping substitution occurred but felt that revascularization was too slow to save the articular cartilage.

Orthopaedic Management of the Arthritic Hip. DR. FRANK STINCHFIELD [9] discussed three well known procedures considered applicable in hip conditions: arthrodesis, mold arthroplasty, and application of the hip prosthesis (Judet). While arthrodesis yielded a painless, stable hip, there were drawbacks and a high incidence of failure of fusion (22 per cent.). Second attempts at arthrodesis had resulted in failures in 50 per cent. Mold arthroplasty had not proved dependable; follow-up had shown that there was persistent limp and gradually the range of movement diminished after the fourth year. For the middle-aged, this procedure seemed preferable, while arthrodesis was better suited to those who do heavy manual labor. Arthroplasty seemed especially indicated in acetabular dysplasia and congenital dislocation. For the old, application of the internal hip prosthesis was better tolerated and was yielding good early results.

Thoroughgoing tabular summaries of the results in each group were included.

Discussing the merits of these procedures, DR. OTTO E. AUFRANC [10] stressed the high incidence of failure in arthrodesis, the aggravation of symptoms in the other hip, and back and knee pain postoperatively. He felt even heavy manual labor was possible after mold arthroplasty and said it was especially to be preferred in cases of old infectious arthritis—in a word, that Dr. Stinchfield's indications for arthrodesis were those for mold arthroplasty. MR. W. ALEXANDER LAW [11] felt that the high incidence of failure of fusion and low-back and knee pain following fusion were deterrents to arthrodesis; he had found mold arthroplasty a more satisfactory procedure even for old sepsis. The Judet operation had yielded excellent early motion, but later much of this movement had been lost. He doubted that the prosthesis could stand the test of time.

Experiences in the Evolution of a New Operation for Osteo-Arthritis of the Hip Joint. MR. JOHN CHARNLEY [12] presented an entirely new and original technique of hip fusion in which central dislocation of the hip joint had been deliberately produced at open operation. Stability was gained through the abutment of the trochanteric portion of the bone against the rim of the acetabulum; the femoral head was left within the pelvis. Actually, rotation and adduction had been found to be impossible. It was even unnecessary to include the knee in the postoperative fixation so that loss of knee function need not occur. Fibrous ankylosis had yielded excellent results because of the stability resulting from the relation of the bones. By means of osseous compression, however, union was possible as early as six weeks after operation. Hospitalization could be reduced to eight weeks. There had been no complications. The report was based upon the follow-up of forty-five patients who had been operated upon during the past four years. The results have been brilliant, all of the patients having returned to work in three to four months.

Discussing the two preceding papers, DR. ARTHUR STEINDLER [13] declared that he was opposed to irreversible operative procedures on the hip joint, except for patients whose chief complaint was pain. DR. JOHN R. NADEN [14] reported from personal experience that a fused hip in good position meant but slight inconvenience to which the patient could easily adapt himself. He had performed Mr. Charnley's operation on one of his patients, was impressed by the method, and had avoided plaster fixation by using a nail for internal fixation which he had driven through the ilium into the femur.

Advantages of Adduction Deformity and Internal Fixation in Ischiofemoral Arthrodesis for Tuberculous Disease of the Hip Joint in the Adult. MR. THOMAS KING [15] presented his reasons for deliberately adducting the hip in the tuberculous joint during the acute stage of the disease. He said that, as the disease became

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[8] 58 St. John's Road, Clifton, Bristol 8, England
[9] 180 Fort Washington Avenue, New York 32, N. Y.
[10] 266 Beacon Street, Boston 16, Massachusetts
[11] 9 Queen Anne Street, London W.1, England
[12] 4 Rusholme Gardens, Manchester 14, England
[13] Mercy Hospital, Iowa City, Iowa
[14] 614 Birks Building, Vancouver, British Columbia, Canada
[15] 2 Collins Street, Melbourne, Victoria, Australia

quiescent, he did a subtrochanteric osteotomy and performed an ischiofemoral arthrodesis with a fibular graft. He then secured the shaft of the femur to the proximal portion by a nail and plate, by means of which the exact desired angle for positioning the hip could be obtained. Mr. King had done three cases by this method.

In the discussion, Dr. Halford Hallock [16] stated that he had avoided internal fixation in hip fusion for tuberculosis because he felt that it spread the disease to the pelvis. He favored early fusion, the operation being undertaken as quickly as the diagnosis was established.

Mr. H. A. Brittain [17] had sent his written discussion of this paper. The use of metal in tuberculous joints seemed to him unnecessary as well as hazardous; the fibula he had found to be less easily vascularized than the tibial graft recommended in the original procedure. He called attention to an additional hazard: flexion and adduction should be avoided since this position brought the sciatic nerve too far forward into the operative field.

Dr. D. M. Bosworth [18] said he fused these hips once he had established the diagnosis; there was no time for adduction to occur spontaneously. He agreed with Mr. Brittain that nail fixation could carry tuberculosis into the pelvis and that the adducted position was a help in ischiofemoral fusion only when the head and neck had escaped destruction.

Mr. Gilbert Parker [19] had employed with satisfaction the ischiofemoral fusion of Brittain in the tuberculous hips of children in whom the adduction had been allowed to occur. Mr. Michael Wilkinson [20] opposed any form of fusion as a result of his having achieved good functional hips in early tuberculosis following chemotherapy and subtotal synovectomy.

Osteoid Osteoma. Mr. John Golding [21] reported a thorough study, especially from the standpoints of diagnosis and etiology, of thirty-four patients with osteoid osteoma, in twenty-six of whom the diagnosis was histologically proved. Pain was boring and constant; there might be local swelling; at operation, the nidus was found to lie within sclerotic bone and was cherry red in color—the result of the high order of vascularity such as that seen in angioma of bone. Because of the success of excision, this procedure seemed preferable; good results had followed x-ray irradiation of surgically inaccessible lesions.

Dr. H. H. Young [22] called attention to sciatic pain simulating disc injury in some femoral lesions. Usually the pain was too severe to justify the long delay necessary for spontaneous healing. Dr. J. R. Moore [23] divided his cases into groups according to the location of the lesion—cortical, cancellous, and subperiosteal forms being recognized. Lesions close to joints could simulate acute arthritis.

Tuesday, July 1

The scientific session was continued through the morning. Summaries of some of the papers presented follow:

Major Determinants of Normal Gait. Reporting the exhaustive studies of gait carried out over a long period of time by a trained group of investigators, Dr. J. B. deC.M. Saunders [24] pointed out the complex interplay of forces which nature called upon to produce a highly efficient and smooth gait. Pelvic rotation, pelvic tilt, the operation of a double-knee extension mechanism, elevation of the heel, and shift of the center of pressure along the foot were the components. Displacement and translation of the center of gravity of the body had been found to describe a low amplitude sinusoidal path having both a horizontal and a vertical excursion. The resulting course was a spiral. Pelvic rotation reduced hip flexion and extension; knee extension-flexion-extension conserved and dissipated energy in a push-pull mechanism. It was found that mechanically the functional length of the lower extremities was increased two and one-half times by this interaction of forces, the excursion of the center of gravity in the vertical and lateral directions being normally within two inches.

The Evaluation of Pathological Gait. Dr. Verne T. Inman [25], who had collaborated in the analysis reported in the preceding paper, presented the next phase in this gait investigation—studies of pathological gaits. The principle involved was stated as follows: "The reduction in range or total loss of one or more of the five major determinants of the lower extremity which contribute to the final displacement of the center of gravity results in exaggeration of the ranges of the remaining determinants. These exaggerated or compensatory mechanisms attempt to preserve the smooth passage of the center of gravity and are outwardly expressed in the characteristic patterns of pathological gait." The principle was illustrated by an analysis of the effect of wearing high heels—reduced hip, knee, and ankle-joint motion.

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[19] 25 The Crescent, Linthurpe, Middlesbrough, Yorkshire, England
[20] Black Notley Hospital, nr. Braintree, Essex, England
[21] 29 Dawson Place, London W.2, England
[22] 102-110 Second Avenue, S.W., Rochester, Minnesota
[23] 3701 North Broad Street, Philadelphia, Pennsylvania
[24] University of California Medical School, San Francisco, California
[25] University of California Medical Center, San Francisco, California

Discussing the two preceding papers, DR. KEENE O. HALDEMAN [26] pointed out that the investigations presented in these reports were possible only through a large staff of highly trained workers and were the result of prolonged, arduous, and brilliant labor. He called attention to the importance in cases of cardiovascular disease of realizing that more energy was expended in walking by persons with artificial limbs than by normal persons. MR. PHILIP WILES [27] stressed the high value and fundamental nature of these studies, calling attention specifically to the help they afforded in appraising hip arthrodesis in instances where that procedure might be proposed. DR. M. BECKETT HOWORTH [28] likened the gait of a person wearing high heels to that of the Symes amputee. He pointed out that the quadriceps femoris was the first muscle affected in leg strain.

Traumatic Paraplegia. MR. F. W. HOLDSWORTH [29] reported on his experience with traumatic paraplegia following fracture-dislocation of the spine at the thoracolumbar level, which included an analysis of sixty-eight patients. He strongly opposed the prevalent attitude of discouragement among surgeons in treating this condition. Such a view was quite unwarranted. Not only could these patients be expected to walk at six months and leave the hospital at ten months, but the chronic invalidism so common following the classical management was inexcusable. Complete motor and sensory loss during the first two days following injury was a sign of the destruction of the cord alone; commonly the lumbar roots escaped injury and could be expected to recover. This means a return of function at the hip joints and ultimately the gait is usually very much better than the tripod walking of the higher-level paraplegic patient. To ensure good results, a vigorous and carefully planned course of treatment was essential. Often local surgery was indicated. Unless neurological symptoms were progressive, surgery was not, however, indicated in the fresh-fracture group with intact articular processes. Unstable fracture-dislocation, on the other hand, with disorganized articulations required open reduction and internal fixation preferably in the form of two plates, one on either side of the spinous process, bolted together. He considered reduction and internal fixation essential to the restoration of root function to the fullest degree possible. Furthermore, reduction was important from the standpoint of spinal statics. After operation, plaster beds were unnecessary. In the entire series there was only one bed sore and no such complications as myositis ossificans or stiff joints. Twenty-one of the patients had been admitted to the hospital some time after the injury; none of these left the hospital in less than two years.

In discussing this paper, MR. E. A. NICOLL [30] endorsed the views expressed in the paper and emphasized that open reduction was not always simple. COL. A. W. SPITTLER [31] called attention to the advantages of the Stryker frame and Foster bed in the nursing management of this group of injuries. He favored the use of bone grafts for internal fixation. DR. LUDWIG GUTTMANN [32], who had had very wide experience in dealing with paraplegics had also abandoned the plaster bed and superpubic drainage. He felt, however, that early operation did not necessarily assure the restoration of root function. He felt that rehabilitation should begin at once and that the goal should be a return to work in seven to twelve months. DR. PHILIP WILSON [33] considered bone-grafting preferable to metal-plate internal fixation. SIR REGINALD WATSON-JONES [34] on the other hand, agreed with Mr. Holdsworth in the use of plates, observing that the plates functioned satisfactorily during the all-important early weeks before bone fusion took place.

Fractures of the Cervical Spine. DR. WILLIAM A. ROGERS [35] presented a clinical study of seventy-seven cervical fracture-dislocations. There had been fifteen deaths, twelve directly chargeable to cord injury and three to pulmonary embolism. Anterior dislocation was the common cause of quadriplegia, although disc protrusions were responsible for some in the hyperflexion group. Hyperextension must also be accepted as a cause of quadriplegia. The mechanism seemed to be compression between an infolding flaval ligament, posteriorly, and a protruded disc or bony proliferation anteriorly. Evidence was presented in the form of an autopsy specimen that anterior dislocation followed by spontaneous reduction could cause cord transection without roentgenographic evidence of fracture or dislocation.

Few patients who had sustained cervical fracture-dislocations escaped some neurological symptoms. In 10 per cent. of the series being reported, cord symptoms had developed or become intensified, not at the time of injury, but subsequently during transport to the hospital or during definitive treatment, the result of careless handling, halter traction, or laryngoscopic intubation. Less than complete functional cord interruption or late onset of neurological symptoms usually meant a good prognosis from the functional standpoint. The common turnbuckle distracting cervical brace had proved satisfactory in protecting the cord during transportation; skull traction had protected the cord at all times during definitive treatment. Skull traction had been highly satisfactory in effecting reduction. Spontaneous fusion had occurred in only 40 per cent. of

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[33] 321 East 42nd Street, New York, N. Y.
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[35] 266 Beacon Street, Boston 16, Massachusetts

the non-operative patients, while fusion had been obtained in over 97 per cent. of the operative patients. Wire internal fixation and fusion seemed, therefore, preferable to prolonged external fixation alone. The operation was usually performed two to three weeks after reduction; the patients were allowed to become ambulatory two weeks after surgery, provided the cervical movements were limited by a light cervical brace. Fusion had taken place in thirty-seven cases in an average of four months. These patients had resumed pre-injury activities in an average of eight months.

MR. V. H. ELLIS [36] stressed the importance of careful protection of the cord as an emergency measure during transportation and at all times during treatment until the neck had become stable. He agreed that skull traction was the best form of cord protection and he favored wire internal fixation and fusion. DR. T. C. THOMPSON [37] felt that cases of fracture of the odontoid process should be fused and advocated the malar fishhook traction.

Adrenocortical Response in Orthopaedic Conditions and Operative Procedures. DR. PHILIP D. WILSON [38] discussed the adrenocortical function in various orthopaedic conditions which had been studied through the eosinophil count. Stress eosinopenia had been found in a high proportion of hospital patients suffering from injuries, infections, and acute low-back conditions; it had been encountered during investigations in patients with bone tumors. Patients entering the hospital for elective surgery did not show the subnormal counts although a profound fall in the number of eosinophils followed directly after surgery. In this group the count had returned to normal or exceeded normal by the second or fourth day; failure to do so indicated a low adrenocortical reserve. Convalescence was often complicated in these patients.

PROF. J. TRUETA [39], discussing the study, said that he felt it significant that orthopaedic surgeons should be interested in investigations into hormonal physiology. He pointed out, however, that eosinophil counts were highly variable and had to be interpreted cautiously. DR. R. BEVERLY RANEY [40] raised the question whether the mechanism in eosinopenia was always the same, for evidence had been adduced that it could occur in adrenolectomized animals.

A Case of Neurological Arthropathy. DR. GORDON PETRIE [41] presented the case history of a carefully studied girl, fourteen years old, who was completely insensitive to pain-producing stimuli throughout the body. Clinical and x-ray changes in her joints gradually developed, particularly in the spine and the lower extremities. The changes were characterized by effusion, marginal hyperplasia, hypermobility of joints, degeneration and destruction of cartilage, with regeneration and reconstruction of bone. It had been possible to carry out operative procedures on the joints without anaesthesia.

Congenital Phalangeal Fusion through Many Generations. MR. IAN PATERSON [42] presented the history and x-ray films of a man who had congenital fusion of the interphalangeal joints of all fingers. By diligent research, he had traced the same characteristic back through three generations descended from the Earl of Shrewsbury and finally to John Talbot, who was born in the latter part of the fourteenth century. The report was extremely well done and most amusingly presented.

WEDNESDAY, JULY 2

The scientific session was resumed on Wednesday, July 2, and continued throughout the morning.

Structural Changes in the Lumbosacral Region and their Significance as Causes of Low-Back Pain and Sciatica. IAN MACNAB [43] reported an investigation done with Dr. R. I. Harris of the structural changes found in the lumbar spine at autopsy, with special reference to the intervertebral discs. Development was found to have reached its zenith toward the end of the second decade, after which degeneration progressed inevitably but slowly over the years. The rate of deterioration seemed to vary markedly among normal individuals, but injury definitely accelerated the process. Traumatic changes were expressed as radial annular tears which occurred in the posterior or posterolateral quadrants. Through these tears, nuclear protrusions occurred, and in them evidences of hemorrhage were found. When these changes were extensive, the disc lost its mechanical entity. The axis of the interbody motion then shifted posteriorly to the small articulations which in turn became the site of traumatic or degenerative arthritic changes; backward spondylolisthesis occurred and in some subjects there was found evidence of nerve-root pressure. In addition to the usual cartilage erosion, bony marginal proliferations, and thickened fibrous capsules, loose bodies were found in the zygapophyseal joint cavities.

These degenerative changes, when advanced, could be identified roentgenographically when films were taken at the extremes of motion, so as to demonstrate the abnormal mobility. Disc degeneration was often present without disc prolapse; when prolapse was found, characteristic roentgenographic features were lacking.

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Spondylolisthesis. Mr. Esmond F. West [44] discussed the etiology of spondylolisthesis and its relation to injury. He felt that trauma was the more probable chief etiological factor.

Dr. J. A. Freiberg [45], in discussing the two preceding papers, advised excision of thickened posterior articular capsules for the relief of pain of sciatic distribution. Mr. A. L. Eyre-Brook [46] raised doubt of the significance symptomatically of many of the lumbosacral anomalies. He agreed that exploration of the intervertebral foramina for the relief of pain of sciatic distribution was indicated when operation failed to disclose disc prolapse. Dr. Don King [47] had been disappointed in anterior fusion for spondylolisthesis when a tibial bone graft had been inserted through the abdominal approach; ultimately the graft fractured where it crossed the avascular disc. Prof. Merle d'Aubigné [48], however, had found the abdominal operation for spondylolisthesis quite successful in his hands. He had removed the disc, replaced it with iliac-bone grafts, and transfixed the lumbar sacral vertebra with a screw. Patients were allowed up in two weeks without immobilization. Mr. Norman Capener [49] propounded the hypothesis that spondylolisthesis might sometimes result from stress fracture of the neural arch. Prof. Sten Friberg [50] expressed the opinion that spondylolisthesis could be due to congenital defects, strain, or acute trauma. He was sure congenital defects were present. Loss of elasticity was the essential feature of disc degeneration.

The Filum Terminale Syndrome. Dr. George Garceau [51] had operated upon three patients with progressive spastic paralysis: two patients who had had moderately severe scoliosis, the other who had had a tuberculous spine in infancy. Full recovery had occurred in two, partial recovery in the other. Division of the filum terminale had resulted in wide separation; undoubtedly the filum terminale had been under considerable tension. In each there had been failure to relieve symptoms by incision of the dura.

In discussing Dr. Garceau's paper, Dr. H. A. Sofield [52] stated that he had had no experience with such cases but that he was much impressed by Dr. Garceau's observations. He wondered whether there was enough mobility of the cord in the canal to allow it to move upward, relieving tension. Might not the paralysis be due to scoliosis in two patients? He also raised the doubt whether, in the one patient relieved by rest and traction, section of the filum terminale would yield permanent relief. He felt studies to answer these questions seemed important.

Dr. Robert W. Johnson [53] had observed a patient with a cystic tumor of the filum terminale who walked with a "straight-back gait" with a wide base. Flexion of the spine was not possible; the gait seemed typical of a lesion of the filum terminale. Dr. E. H. Wilson [54] presented cases of paralysis aggravated by flexion of the cervical spine and the upper portion of the thoracic spine. Improvement had ensued after rest. Good results had been obtained following fusion of the upper portion of the spine in this group.

Dr. Arthur Steindler [55] presented his results in patients who had paralysis as a complication of scoliosis. He called attention to von Recklinghausen's observation that ascension of the spinal cord was sometimes prevented in spina bifida by adhesions; Dr. Garceau's cases might be analogous.

In closing, Dr. Garceau stressed that he was reporting merely anatomical observations and could not give proof of his findings. Many of the doubts raised he could not eliminate. He did, however, feel that it was unlikely that scoliosis was responsible because in one instance there had been upper-extremity paralysis above the lesions and he had observed no adhesions.

Ischaemic Contracture—Local in the Hand. Dr. Sterling Bunnell [56] discussed the etiology, pathological changes, clinical features, and treatment of ischaemic contracture involving the intrinsic muscles of the hand. He pointed out that swelling of the hand too tightly encased in plaster-of-Paris or diminished circulation from vascular injury in the forearm was responsible for this crippling condition. He called attention to the condition as a distinct entity, although it might occur in conjunction with Volkmann's contracture which is confined to the forearm. The deformity is the opposite of the paralytic claw-hand, there is inability to open the hand for grasping. The metacarpophalangeal joints are flexed, the interphalangeal joints are in extension, and the thumb is fixed in the abducted position. Prophylactic measures include prevention of further curtailment of the circulation in the hand. When there is residual intrinsic muscle function, stripping of the interossei from their attachment to the metacarpals has the effect of lengthening these muscles, thus allowing the hand to open. When there is extensive fibrosis of the intrinsic hand muscles, the lateral bands of insertion should be tenotomized. The abduction deformity of the thumb was freed by incision of the soft parts within the

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[51] 23 East Ohio Street, Indianapolis 4, Indiana
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[53] 4 East Madison Street, Baltimore, Maryland
[54] 380 East Town Street, Columbus 15, Ohio
[55] Mercy Hospital, Iowa City, Iowa
[56] 516 Sutter Street, San Francisco 2, California

first cleft, opposition of the thumb being maintained with an intermetacarpal bone graft fixed with a Kirschner wire. The resulting defect was covered by a free or pedicled skin graft.

DR. LEO MAYER [57], in line with Dr. Bunnell's description of causes of ischaemia, re-emphasized the necessity of avoiding tight bandaging after hand surgery. He felt that advancement of muscle origins or tenotomy, if contractions were the cause, were procedures which it was important to recognize if improvement was to be expected.

MR. GUY PULVERTAFT [58] stressed the importance of the after-care following the treatment outlined by Dr. Bunnell. This should be prolonged, for he had found a tendency to relapse due to re-forming of the lateral bands. To this end, appropriate splints and elastic traction were necessary.

Care of the Crippled Child in the United States. DR. A. R. SHANDS [59] reported that 60 per cent. of the 700,000 crippled children of the United States are under treatment. He called attention to the eighty-two hospitals in the country with a bed capacity of 13,000 devoted solely to the care of crippled children, and he stressed the fact that there existed an occupancy percentage of 75. Neuromuscular disorders accounted for 36 per cent. of patients, congenital deformities for 30 per cent., developmental conditions for 28 per cent., and infections for 7 per cent. An estimate of current costs had been given at $30,000,000 annually. This included educational opportunities in most states as well as vocational rehabilitation programs. There were 220 accredited residencies. In closing, Dr. Shands emphasized the great contribution made by Dr. Michael Hoke and the Shriners' Hospitals to the care of crippled children in America.

The afternoon was devoted to clinical demonstrations held at the Royal National Orthopaedic Hospital and Institute of Orthopaedics, Stanmore. Here lunch was served, and from 2:00 until 5:00 P.M. the members of the Associations and their guests attended clinical demonstrations and presentations of investigations in the basic sciences. In this remarkable Hospital and Institute, devoted to clinical and scientific research and development in orthopaedic surgery, the visitor finds a happy blending of pure science and technology as they are applied to surgery. The facilities in every respect in both fields seemed unlimited. Interest was unbounded, and in the three hours allotted to the visitor one could hardly hope to gain more than a very superficial impression of the splendid work being done at the Hospital and Institute. Surely one cannot fully appreciate the vigor of British orthopaedic surgery and the brilliant future which lies ahead of it until he has visited Stanmore.

It would be impossible to include in the limited space available descriptions of the brilliant demonstrations presented throughout the afternoon. Those giving demonstrations and their subjects were as follows:

The Effect of Cortisone on Experimental Fractures, Epiphyseal Growth, and the Healing of Muscle.
Dr. C. F. Hadfield

Bacteriological Aspects of Skeletal Tuberculosis: Bacterial Chondrolysis.
Dr. C. H. Jack

Low Blood Pressure Anaesthesia.
Dr. G. E. Enderby

Spinal-Cord Changes in Poliomyelitis.
Mr. W. J. Sharrard

Experimental Work in the Application of Plastics in Orthopaedic Surgery.
Dr. J. Scales

The Measurement of Anteversion in Congenital Dislocation of the Hip.
Mr. Shelswell

Replacement of Bone by Plastic Prostheses.
Dr. J. Scales and Mr. H. J. Burrows

Kite Technique in the Treatment of Club-Foot.
Mr. A. T. Fripp

Judet Arthroplasty of the Hip Joint.
Mr. K. I. Nissen

Adolescent Coxa Vara.
Mr. P. H. Newman

Pectoral Transplants for Biceps Paralysis. Preventive Tendon Transplants in the Foot. Fascial Sling for Trapezius Paralysis. Nerve Grafts.
Mr. H. J. Seddon and Mr. D. M. Brooks

Ischiofemoral Arthrodesis of the Hip Joint.
Mr. J. A. Cholmeley

Treatment of Skeletal Tuberculosis by Streptomycin.
Dr. F. H. Stevenson

57. 1150 Fifth Avenue, New York, N. Y.
58. 27 Friargate, Derby, England
59. Alfred I. duPont Institute, Wilmington, Delaware

Scoliosis. Surgery of the Hand. Epiphyseal Arrest.
Mr. J. I. P. James
Congenital Dislocation of the Hip.
Mr. H. J. Seddon and Mr. D. Trevor
Paraplegia in Tuberculosis of the Spine.
Mr. H. J. Seddon
Suture of Extensor Pollicis Longus.
Mr. D. Trevor
Biochemical Experiments in Ossification.
Dr. T. F. Dixon
Cold Vasodilatation.
Mr. G. L. W. Bonney

There were also shown roentgenographic and photographic displays, as well as the work of the Metabolism Unit.

THURSDAY, JULY 3

The morning of July 3 was devoted to the presentation of papers.

Capsular Arthroplasty for Congenital Dislocation of the Hip Joint. DR. PAUL C. COLONNA [60] reported the results which he had obtained over a period of twenty years with his operation of capsular arthroplasty for congenital dislocation of the hip. The procedure was indicated for unreduced bilateral dislocations in children of three to six years of age; for unilateral dislocation the age limits were three to eight years. Some very remarkable results had been obtained, approaching the normal in the range of movement, stability, and freedom from pain. Some of these children had been followed into adulthood and showed no evidence of joint incongruity or degenerative changes. Preliminary traction was considered essential. A deep cup-shaped acetabulum was created at the anatomical site for the acetabulum; the femoral head was placed within this cup, the capsule having previously been sutured around it and so interposed between the femoral head and the wall of the newly created acetabulum. Exceptionally, a shelf was necessary years afterward to impart added stability. If anteversion was marked, a supracondylar osteotomy was done early in the convalescence.

Posterolateral Approach in the Treatment of Congenital Dislocation of the Hip Joint. DR. ALEXANDER GIBSON [61] described his method of treatment of congenital dislocation of the hip by open operation, using the posterolateral approach. He divides the superior portion of the capsule transversely and reflects the medial portion of the attenuated capsular flap along with a thin layer of bone from the ilium. The reflection is carried down to the level of the rim of the true acetabulum. The femoral head is gently replaced and the medial capsular layer is made to overlap the lateral portion of the remaining capsule. In this way he obliterates the superior capsular recess and deepens the acetabulum.

SIR HARRY PLATT [62], in discussing the preceding two papers, approved of open reduction only when the gentle manipulative reduction resulted in an unstable eccentric relationship at the new joint. He felt reconstructive procedures should be limited to creation of shelves. DR. J. E. MILGRAM [63] said that he had been disappointed in his results with the Colonna method; he had, however, reviewed Dr. Colonna's own cases clinically and had found them to be surprisingly encouraging. He had had difficulty in determining just where to place the deepened acetabulum. He felt that the Colonna method was valuable in selected cases. MR. H. J. SEDDON [64] raised the question as to what procedures should be used for children with unreduced dislocations who were too old for capsular arthroplasty and too young for a mold arthroplasty or prosthesis. He had reserved Dr. Colonna's operation for the difficult age group, eight to fourteen years, but he had had less satisfactory results; the hips were very stiff. He felt, however, that in spite of this, the procedure was very worth while because the position was a good one for subsequent arthrodesis or arthroplasty. DR. G. W. N. EGGERS [65] preferred the posterolateral approach for reconstructive procedures on the hip. DR. F. E. WEST [66] added a word of warning that the Colonna operation was hazardous in bilateral cases. He felt that it was no procedure for the inexperienced surgeon. MR. J. B. COLQUHOUN [67] felt that many patients on whom there had been unsuccessful attempts at reduction by manipulation had been selected for the Colonna operation and that it was not surprising that the results were less favorable than those obtained by Dr. Colonna himself, who had employed his procedure often under more favorable circumstances. In closing DR. COLONNA stressed the great importance of careful selection of cases for his operation.

Diagnosis of Shoulder Lesions Arising from Injuries of the Rotator Cuff. MR. V. H. ELLIS [68] presented a two-phase test to aid in establishing a sound diagnosis in recent shoulder injuries. If, after procaine injection

[60] Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania
[61] 601 Medical Arts Building, Winnepeg, Manitoba, Canada
[62] 11 Lorne Street, Manchester 13, England
[63] 950 Ocean Avenue, Brooklyn, New York
[64] Royal National Orthopaedic Hospital, London W.1, England
[65] 2201 Avenue "D", Galveston, Texas
[66] 211 Medico-Dental Building, San Diego, California
[67] 85 Spring Street, Melbourne, Victoria, Australia
[68] 14 Wimpole Street, London W.1, England

into the suspected region, the range of active abduction increased markedly, no more than a minor tear or only reflex inhibition was present. If, however, no favorable response to injection ensued, he proceeded to arthrography. Arthrograms seem to provide a reasonably accurate means of estimating the presence and extent of cuff tears. Operative repair of large tears was indicated. MR. J. B. COLQUHOUN and DR. TOUFICK NICOLA [69] had employed iodine arthrography and found it valuable. In closing, MR. ELLIS warned that abduction of 90 degrees following procaine injection did not eliminate the diagnosis of a major tear.

The Area of Fusion in Scoliosis. DR. JOHN COBB [70] presented his large experience in the management of scoliotic patients, discussed the indications and contra-indications for fusion, and the areas which, in his opinion, should be fused. He believed that a high percentage of the curves in patients up to fourteen years could be corrected by plaster jackets, subsequently fused, and the correction maintained. He believed that the area of fusion should be accurately estimated geometrically, and disagreed with the belief that it was necessary to fuse between parallel lines in all cases. Confusion existed about the meaning of the term "correction", which applied not to eliminating the entire primary curve but to correcting the angular deformity. Thus, if the side bending toward the concave side of the primary curve only partly eliminated the compensatory curves, the primary curve should be only partly corrected. The area of fusion must then be selected so as to counterbalance the uncorrectable deformity. When, however, correction of the primary curve fell short of the maximum which was permissible, it might be necessary to extend the area of fusion beyond the parallels above and below, well into the compensatory curves.

Idiopathic Scoliosis, Prognosis, Diagnosis, and Operative Indications Related to Curve Patterns and Age of Onset. MR. J. I. P. JAMES [71] had found that the prognosis was worse the higher the apex of the curve, and in the main the younger the patient at the time of onset. The most benign group included adolescent patients with curves, while the most severe deformities occurred in the infantile idiopathic thoracic group. Fusion seemed most often necessary for pain and severe deformity in thoracic cases.

DR. CLAUDE LAMBERT [72], in discussion of these two papers, felt that it was not always possible to apply general rules in the management of scoliosis and pointed out that operation might be indicated at any level for severe progressive deformity, even in children under ten years of age. MR. H. OSMOND-CLARKE [73] called attention to the possibilities of growth arrest at the epiphyseal cartilaginous plates of the vertebrae as a means of controlling scoliosis. DR. J. R. MOORE [74] had not been able to follow Dr. Cobb unreservedly for he felt that a curve could hardly be considered stable until growth had ceased. He felt that Dr. Cobb's thesis would have to be supported by convincing statistical data.

Ulnar Neuritis from Ganglion Pressure. MR. H. J. SEDDON [75] presented the histories of five patients upon whom he had operated because of spontaneous onset of paralysis of the muscles of the hand supplied by the ulnar nerve. The cause of paralysis in four of the five patients was found to be a ganglion arising from the carpal joint in or near the volar and ulnar aspect of the wrist joint. The operation consisted in division of the transcarpal ligament, and carrying the section down to the region of the motor branches of the ulnar nerve at the level of the wrist joint. Ganglia were discovered and were removed with relief of symptoms.

Etiology of Carpal Tunnel Compression of the Median Nerve. MR. K. I. NISSEN [76] reported that the common type of carpal tunnel compression of the median nerve is secondary to a chronic non-specific proliferative tenosynovitis without effusion. In long-standing cases there is dense tubular fibrosis around the tendon of the flexor pollicis longus and a bluish-grey membranous thickening of the other sheaths. For this reason, the extremes of flexion of the thumb and, to a lesser degree of the fingers, are limited. These synovial changes, associated with maximal compression, grade imperceptibly into a more bulky form with some effusion and finally into one type of compound palmar ganglion with minimal compression. The condition must be differentiated from rheumatoid arthritis.

At 5:15 P.M., by invitation of the President of the Royal College of Surgeons of England, members and guests of the Associations met in the Hunterian Museum at the College and listened to the scholarly and inspiring Moynihan Lecture delivered by DR. LEO MAYER on *The Development of Tendon Surgery.* After the lecture, all assembled adjourned to the Hall of the College where sherry was served. It was characteristic of the entire week that each event seemed the best; this foregathering was no exception.

FRIDAY, JULY 4

The scientific sessions were brought to a close on Friday, July 4, at the close of the morning's program. The following are summaries of the papers presented.

Treatment of Causalgia. MR. ROLAND BARNES [77], discussing causalgia after injury of the main nerve trunk, noted that the constant burning pain was felt beyond the area of distribution of the involved nerve,

[69] 96 Gates Avenue, Montclair, New Jersey
[70] 333 East 43rd Street, New York 17, N. Y.
[71] Royal National Orthopaedic Hospital, London W.1, England
[72] 104 South Michigan Avenue, Chicago, Illinois
[73] 80 Harley Street, London W.1, England
[74] 3701 North Broad Street, Philadelphia, Pennsylvania
[75] Royal National Orthopaedic Hospital, London W.1, England
[76] Gable End, 37 Uxbridge Road, Stanmore, Middlesex, England
[77] 5 Ledcameroch Crescent, Bearsden, Glasgow, Scotland

was aggravated by emotional stimuli, and might be accompanied by trophic disorders. In spite of relief from sympathectomy, the interruption of afferent sympathetic pathways did not seem responsible for the improvement, nor did the consequent vasodilatation explain the relief. He felt that the benefit seemed most probably to be due to the section of efferent sympathetic fibers which stimulated the nerve trunk at the site of injury. Such a mechanism alone seemed to explain satisfactorily the relief so commonly obtained from nerve block distal to the lesion and from complete section of the nerve.

In the discussion, Mr. D. Lloyd Griffiths [78] emphasized that, although it was rare, causalgia did persist after complete nerve section. He felt, however, that failure to relieve by sympathectomy means an inadequate operation. Dr. I. W. Nachlas [79], on the other hand, felt there was much variation among cases and that at times sympathectomy, no matter how complete, might fail.

Tuberculosis of Bones and Joints. Dr. D. M. Bosworth [80] discussed his impressive experience with the use of the chemicals isoniazid and, in those instances where that drug had seemed to be ineffective, iproniazid in the treatment of a series of patients over a period of eight months. Streptomycin, as an adjunct to conservative treatment and surgery, had been previously studied. Marked improvement in the vast majority of cases had occurred. Some patients, however, did not respond to the use of streptomycin; consequently, the newer chemicals were used. The results of the use of these newer drugs were apparently striking in the effect on the general well-being of the patient and in the closing of sinuses which had been in existence for many months or years. The author stated, however, that the use of the drugs had been carried out for a relatively short time; therefore, conclusions were a bit unwarranted at this time. The toxic effects of the drugs were emphasized.

Problems of Neurofibromatosis as Related to Orthopaedic Surgery. Dr. H. R. McCarroll [81] discussed the findings in more than 100 cases of neurofibromatosis, with clinical orthopaedic manifestations, to be classified under cutaneous, subcutaneous, skeletal, vascular, and lymphatic types of involvement. Various methods of handling these cases were discussed, particularly the surgical approaches. Many beautiful colored slides were used to illustrate the discussions.

Results of Excision of the Patella. Dr. H. H. Boucher [82] discussed his experience with excision of the patella in 105 patients for fracture, chondromalacia, and recurrent dislocation. The diagnosis of chondromalacia could be difficult in its early stages; painful crepitus was a useful sign. Results were good in almost all cases and the patients were satisfied, although some late aching was common. The more serious complications included incomplete rupture of the quadriceps (two patients) and complete rupture (two patients). Bone re-formed within the tendon might result in a return of pain.

Excision of the Patella. Mr. R. H. Sewell [83] dealt with a different type of patient than did Dr. Boucher, in that his patients were, on the whole, in an older age group. In many instances this presented more difficult problems. His inclination was to excise patellae for hypertrophic conditions, but he was not enthusiastic about the excision of the patella for chondromalacia. Mr. Sewell had also excised the patella for recurrent dislocation with gratifying results in eight out of ten cases, but he discouraged the excision of the patella in the rheumatoid type of disease.

Dr. Edwin F. Cave [84], discussing the two preceding papers, stressed the importance of longer exploratory incisions to allow thorough exploration of the articular surface of the patella. Such policy had resulted in the earlier diagnosis and in establishing the existence of the higher incidence of the condition. All agreed that excision was the treatment of choice for comminuted fractures. Dr. Cave favored suture for transverse fractures and agreed that excision was justified in recurrent dislocation. He felt patelloplasty was preferable to complete excision.

Posterior Subtalaid Fusion in the Treatment of Fractures of the Os Calcis. Mr. I. Lawson Dick [85] considered fusion indicated in selected cases, and presented an ingenious technique for posterior arthrodesis which did not require plaster immobilization of the region.

Orthopaedic Aspects of Leukaemia. Mr. D. Lloyd Griffiths [86] pointed out the clinical manifestations of an orthopaedic nature which he had observed in eleven cases of leukaemia during the past two years. These included pain in the limbs, backache, sciatica, limp, and even paraplegia. Destructive lesions of bone appeared in the roentgenograms as metaphyseal zones of translucence, as focal erosions, or as diffuse infiltrations—all seemingly associated with nature's attempt to extend the marrow tissues. There might occur extensive infarction in bone, often not apparent roentgenographically. Subperiosteal bone might form as well as sclerotic areas; the latter were found chiefly in the vertebral bodies. The antifolic drugs and ACTH seemed to produce remissions which were only temporary. Leukaemia is not uncommon; it now ranks sixth as a cause of death in children. The diagnosis was confirmed by sternal puncture.

[78] 14 St. John Street, Manchester 3, England
[79] 1109 North Calvert, Baltimore, Maryland
[80] 742 Park Avenue, New York 21, N. Y.
[81] 3720 Washington Avenue, St. Louis 8, Missouri
[82] Room 402, Medical Dental Building, Vancouver, British Columbia, Canada
[83] 10 Dartmouth Court, Dartmouth Grove, London S.E. 10, England
[84] 262 Beacon Street, Boston 16, Massachusetts
[85] 29 Fairherston Place, Edinburgh, Scotland
[86] 14 St. John Street, Manchester 3, England

Mr. H. Jackson Burrows [87] brought out in his discussion that leukaemia was sometimes confused with senile osteoporosis. In the absence of atrophy of pelvis and hands, one's suspicion would naturally be aroused and sternal puncture be performed.

Posterior Peripheral Detachment of the Lateral Meniscus. Mr. E. A. Jack [88] discussed what he believed to be a clinical entity—namely, tear of the posterior peripheral attachment of the lateral meniscus. He referred to Last's description of the popliteus muscle (*The Journal of Bone and Joint Surgery*, 32-B: 93-99, Feb. 1950) and stated that he believed the mechanism of production of the lesion was that of acute flexion of the knee. He described what he thought to be an original observation of an extra slip of tendon, originating from the popliteus tendon and attaching to the posterior portion of the lateral meniscus as well as to the head of the fibula.

In the discussion, Mr. I. S. Smillie [89] said that he had found the entity in approximately 12 per cent. of lateral meniscectomies and in 4 per cent. of all excisions of the meniscus. Dr. D. H. O'Donoghue [90] recognized the condition and had classified it in his own mind along with posterior and bucket-handle tears. Dr. José Valls [91] had also recognized the lesions and referred to the condition as "popliteus hiatus syndrome". Mr. Jack, in closing, added that the tear was through vascular tissue and might, therefore, heal spontaneously with rest.

The afternoon of Friday, July 4, was devoted to clinical demonstrations at the orthopaedic services of the many London hospitals. The programs follow.

Middlesex Hospital.

Angiography in the Diagnosis of Bone Tumors.
Mr. D. Sutton

Results of Decompression of the Carpal Tunnel for Median-Nerve Symptoms.
Mr. J. Golding

A Follow-up Series of Compression Arthrodeses of the Knee.
Mr. P. R. N. Kerr

Chandler's Lumbosacral Fusion with Bone-Bank Rib.
Mr. P. H. Newman

Fifty Cases of Osteochastoma.
Mr. Philip Wiles

A film on the clinical applications of the functional anatomy of the low back by Mr. Silver, Mr. Golding, and Mr. Floyd was also shown.

St. Bartholomew's Hospital. After a reception in the Great Hall, there was an exhibition of the archives of the Hospital with specimens, writings, and publications of orthopaedic work. Included among these were the works of Percivall Pott, James Paget, Reginald Cheyne Elmslie, and Gauvain. Sir James Paterson Ross, K.C.V.O., and Mr. J. B. Kinmonth gave a demonstration of investigations into various forms of arteriovascular disorder. Dr. E. F. Scowen and Dr. Archer demonstrated a clinical investigation of metabolic and endocrine diseases of the skeleton. Late in the afternoon, there were clinical discussions and the presentation of films in the Medical and Surgical Theatre.

St. Thomas's Hospital. A clinical demonstration was given by the Orthopaedic Staff of St. Thomas's Hospital: Prof. George Perkins, Mr. Ronald Furlong, Mr. F. A. Simmonds, Mr. A. G. Apley, Mr. M. Pickering-Pick, and Mr. D. R. Urquhart.

Royal Free Hospital School of Medicine.

Demonstration of Osteochondritis Dissecans.
Mr. C. Gray

Demonstration of Dysplasia Epiphysialis Multiplex Congenita.
Mr. C. Gray and Mr. R. H. Maudsley

Applied Anatomy of Bone.

Relative Protrusion of the First and Second Metatarsal Bones.
Mr. C. H. Barnett and Mr. J. R. Napier

The Calcar Femorale and Its Influence on Trochanteric Fractures of the Femur.
Mr. M. Harty

Applied Anatomy of Joints.

The Blood Supply of Joint Structures.
Mr. D. V. Davies

Demonstrations of the Circulus Articuli Vasculosus of William Hunter.
Mr. M. Harty

Fibular Rotation in Relation to Movements at the Ankle Joint.
Mr. C. H. Barnett and Mr. J. R. Napier.

[87] 25 Upper Wimpole Street, London W.1, England
[88] Kingarth, Colington, Edinburgh, Scotland
[89] Balcarres, Albany Road, Broughty Ferry West, Dundee, Scotland
[90] 1403 Glenwood Avenue, Oklahoma City, Oklahoma
[91] Maipú 753, Buenos Aires, Argentina

Observations on Prenatal Development of the Intervertebral Disc in Man.
The late Mr. Peacock

Cases of Intervertebral Disc Injured by Lumbar Puncture.
Mr. A. H. Baker

Experimental Studies of Regeneration of Rat Tendon.

Collagen Deposition in Repairing Tendons.
Mr. D. W. James

Ossification in Regenerating Rat Tendon.
Mr. R. C. Buck

Experimental Studies on Skeletal Muscle in the Rabbit.

Regeneration of Devascularized Muscle and Its Subsequent Innervation.
Mr. J. T. Aitken, Mr. D. B. Allbrook, and Mr. D. D. B. Morris

Studies of Recovery of Function after Peripheral-Nerve Injuries in Man.

Changes in Structure of Voluntary Muscle.
Mr. E. Guttmann and Miss R. E. M. Bowden

Simple Tests for Assessing Motor Recovery in the Upper Limb, the Advance of Tinel's Sign, and the Use of Footprints in Assessing Dysfunction and Designing Corrective Appliances.
Mr. J. R. Napier

The Recovery of Cutaneous Sensibility.
Dr. J. Whillis, Miss R. E. M. Bowden, and Mr. J. R. Napier

The Rate of Advance of Recovery of Motor Function after Radial-Nerve Lesions in Man.
Miss R. E. M. Bowden and Mr. D. A. Sholl

The Incidence of Contractures.
Miss R. E. M. Bowden and Mr. J. R. Napier

Physiological Rest.
Mr. Norman Capener

The Effect of Mobilization of the Nerve upon Recovery of Function after Suture of the Ulnar Nerve.
Miss R. E. M. Bowden

Study of Factors Influencing Social and Industrial Resettlement of Patients with Nerve Injuries.
Mr. D. Russell Davies

Re-Innervation of Denervated Muscle by the Implantation of a "Foreign" Muscle Nerve, Sequelae of Partial Denervation of Muscle, Use of Muscle Grafts to Follow the Process of Muscle Regeneration and Re-Innervation, and the Effect of Reduction of Blood Supply on Electromyographs.
Mr. J. T. Aitken, Mr. D. B. Allbrook, and Mr. D. D. B. Morris

Strain Gauge Methods in Anatomical and Physiological Research from the Working Efficiency Section of the Medical Research Council Unit for Research on Climate and Working Efficiency, Department of Human Anatomy, Oxford.

Strain Gauge Dynamometer and Strain Gauge "Plethysmograph".
Mr. H. D. Darcus and Mr. R. J. Whitney

Measurements of Amplitude of Pronation and Supination, and of Humeral Rotation.
Mr. H. D. Darcus and Mr. N. Salter

Experimental Studies in Anterior Poliomyelitis.

Experimental Models of Poliomyelitic Infection.
Mr. F. K. Saunders

Changes in Skeletal-Tissue Muscle of the Rhesus Monkey after Anterior Ramisection and Experimental Anterior Poliomyelitis.
Miss R. E. M. Bowden.

Recovery of Sensibility in Full-Thickness Skin Grafts.
Mr. J. R. Napier

Function of the Human Hand from Birth to Adult Life, and Investigation of Proprioceptive Function in Handling Objects.
Dr. J. Whillis and Mr. F. G. Ellis

Electromyographic Study of the Activity of the Lower Limb Muscles in Man during Standing.
Mr. A. Nightingale and Mr. J. Joseph

Guy's Hospital. The demonstrations included various methods of treatment of chronic arthritis of the hip including some experiments in arthroplasty, developments in the conservative treatment of disc lesions with demonstrations of treatment by traction, and "preventive surgery" of the foot. Cases of unusual interest were presented and there was a worth-while exhibit of roentgenography, appliances, and pathological specimens.

King's College Hospital, Denmark Hill. Here groups of patients were shown to demonstrate: arthroplasty of the hip—treatment in bed and late results; tendon injuries of the hand; surgery of the mandible; surgery of the wrist joint and compound palmar ganglion; double fractures of the lower limb; and self help for the

disabled. Unusual cases were presented; during tea in the Board Room, roentgenograms and pathological specimens of interest were displayed.

The London Hospital.

Putti-Platt Repair of Recurrent Dislocation of the Shoulder.
Mr. H. Osmond-Clarke

Treatment of Femoral-Neck Fractures.
Mr. O. J. Vaughan-Jackson

Spinal Osteotomy and Mold Arthroplasty of the Hip.
Mr. W. Alexander Law

Recurrent Forward Dislocation of the Ankle Joint.
Sir Reginald Watson-Jones

Tumors of Bone and Calcium Metabolism.
Prof. Dorothy Russell

Management of Bone Infection.
Prof. Bedson

Prevention of Wound Sepsis.
Mr. F. C. O. Valentine

Results of Deep X-Ray Therapy on Bone Tumors.
Dr. S. Cochrane Shanks

Excision of the Trapezium for Osteo-Arthritis.
Mr. H. A. Pearce

Treatment of Pott's Disease with Isonicotinic Acid Hydrazide. Unusual Charcot's Joints.
Mr. M. B. Devas

Examples of General Affections of the Skeleton. The Treatment of Dupuytren's Contracture.
Mr. C. G. Attenborough

Roentgenographic Demonstrations of Sky-Line Views of the Carpal Tunnel, Olecranon, and Patella; High-Voltage Roentgenography of Infected Bones; Bone-Length Measuring without Special Apparatus; Studies of Calcaneonavicular Bars, Cervical Spondylosis, and Strain Films of Fractures; Roentgenographic Control of the Treatment of Scoliosis; Useful Implements in Orthopaedic Roentgenography.
Miss Vaughan

Technique of Theater Cinematography.
Mr. Ruddick

The week of the Meeting, socially, was replete with delightful gatherings. There could be no more hospitable hosts than those who gave us such a memorable good time amidst such congenial surroundings. On Sunday, besides the Reception by the President of The British Orthopaedic Association, Sir Reginald Watson-Jones, and Lady Watson-Jones, there were numerous luncheons, suppers, and other parties. Monday was given over to club and private dinner parties. On Tuesday, in the afternoon, there was the golf tournament, the winner to receive the Robert Jones Golf Cup, while in the evening came the inimitable Sadler's Wells Ballet at Covent Garden. Supper parties followed. On Wednesday came other club and private dinner parties. On Thursday, in the afternoon, came the Reception of the Lord Mayor and the Lady Mayoress of London at Mansion House, and, in the evening, the Banquet of the Orthopaedic Associations. The special toasts were "The Guests", proposed by Sir Harry Platt with a reply from the Minister of Health, Mr. Ian MacLeod; "Orthopaedic Surgery", proposed by Dr. F. A. Chandler, President of The American Orthopaedic Association, with response by Sir Reginald Watson-Jones, President of The British Orthopaedic Association; and "The English Language", proposed by Lord Reading with response by the Right Honorable Lord Justice Birkett. One may live many years without listening to such brilliant after-dinner speeches as those presented. Friday night was given over to the Hurlingham Ball, given in recognition of American Independence Day and in relaxation from the efforts of the week. There were dancing, light refreshments, cabaret (with the support of Miss Mary Martin and Mr. Noel Coward who were so kind as to entertain us), and firework displays.

On Saturday, July 5, visits had been arranged to:

The Royal Victoria Plastic and Facio-Maxillary Hospital, East Grinstead, and the Royal Air Force Rehabilitation Centre, Headley Court;

The Heritage, Chailey, a school and hospital run on the lines of an English public school and serving the needs of such crippled children from any part of the country as are best suited by a boarding school;

Canterbury, to see the Cathedral and the Roman Steps;

Black Notley Hospital, near Braintree, Essex, to attend clinical demonstrations, including follow-up results after curettage of tuberculosis of the spine and synovectomy of the hip and knee, and late results of slipped epiphysis after nailing;

The Fifth Hospital Group, United States Air Force, Burderop Park Hospital, Swindon, for a tour of the Hospital and for clinical programs.

From Sunday, July 6, to Saturday, July 12, the orthopaedic centers of England and Scotland were open to visitors for special programs designed to present the work being done. Special tours had been arranged:

MONDAY, JULY 7

Exeter. A clinical meeting was held at the Princess Elizabeth Orthopaedic Hospital under the direction of Mr. Norman Capener.

Norwich. The visiting orthopaedic surgeons were invited to attend the opening of the new operating suite by H. R. H. Princess Margaret. Visiting surgeons and their wives were presented to Her Royal Highness by Mr. H. A. Brittain.

Oswestry. A clinical meeting at the Robert Jones and Agnes Hunt Orthopaedic Hospital was held under the direction of the Visiting Staff and the Secretary-Superintendent, Mr. J. C. Menzies.

WEDNESDAY, JULY 9

Liverpool. A plaque on the ruins of 11 Nelson Street, in memory of Hugh Owen Thomas, Robert Jones, and T. P. McMurray, was ceremonially unveiled by the President of The Australian Orthopaedic Association, Esmond F. West, Esq. A clinical meeting was held.

Bath. A clinical meeting was held under the direction of Mr. J. Bastow.

THURSDAY, JULY 10

Birmingham. A clinical meeting was held at which were shown patients illustrating reconstruction procedures in the upper limb after severe peripheral-nerve palsy (Mr. A. M. Hendry), tendon transplants in the correction of congenital talipes equinovarus (Mr. T. S. Donovan), the use of the Thomas wrench (Mr. F. Wilson Stewart), and bone lengthening (Mr. F. G. Allan).

FRIDAY, JULY 11

Oxford. A clinical meeting was held at the Wingfield-Morris Orthopaedic Hospital.

SATURDAY, JULY 12

Edinburgh. Reception of visiting orthopaedic surgeons by the President of the Royal College of Surgeons of Edinburgh, Prof. Walter Mercer. A clinical meeting was held.

One not so fortunate as to have been able to attend can scarcely imagine a more successful meeting, one that was pleasanter, more stimulating, rewarding, conducive to the free interchange of ideas—in a word, one more completely satisfying. To the officers and the program secretaries of the participating Associations go the thanks of an appreciative membership. To The British Orthopaedic Association: Sir Reginald Watson-Jones, President; Mr. Philip Newman, Secretary; the Organizing Committees in Great Britain; to the Congress Secretaries, Miss B. M. Key, Miss M. W. Robertson, and Miss S. M. Perry; to Miss Jean Barnes; to the Ladies Committee; and to the kind and hospitable people met everywhere one went in Great Britain heartiest thanks are due for hospitality which can hardly be surpassed and for a meeting which will long be remembered as one of the best.

BOOKS RECEIVED

The Battle for Mental Health. James Clark Moloney, M.D. New York, Philosophical Library, 1952. $3.50.

Building Happy Useful Lives for the Handicapped. A Record of the 1950 Convention of The National Society for Crippled Children & Adults. Chicago, 1951. $1.25.

Cellular Changes with Age. Warren Andrew, Ph.D., M.D. Springfield, Illinois, Charles C. Thomas, 1952. $2.50.

Doctors Differ. Harley Williams. Springfield, Illinois, Charles C. Thomas, 1952. $5.50.

Infective Hepatitis. Studies in East Anglia during the Period 1943–47. F. O. MacCallum, A. M. McFarlan, J. A. R. Miles, M. R. Pollock, and C. Wilson (Privy Council, Medical Research Council, Special Reports Series, No. 273). London, His Majesty's Stationery Office, 1951. 4 shillings, 6 pence.

Inhalation Anesthesia, Ed. 2. Arthur E. Guedel, M.D. New York, The Macmillan Company, 1951. $3.75.

The Medical Annual, 1952. A Year Book of Treatment and Practitioners' Index. Edited by Sir Henry Tidy, K.B.E., M.A., M.D.(Oxon.), F.R.C.P., and A. Rendle Short, M.D., B.S., B.Sc., F.R.C.S. Bristol, John Wright & Sons Ltd.; London, Simpkin Marshall Ltd., 1952.

Nouvelle Pratique Chirurgicale Illustrée, Fascicule 5. Jean Quénu. Paris, G. Doin & Cie., 1951. 1.650 fr.

Traumatismos Obstétricos do Ombro. Dr. Waldemar Rosa dos Santos. Rio de Janeiro, Editoria Capitólio, 1950.

Wiederherstellungs-Chirurgie des Gesichts. R. Perwitzschky, Berlin, Walter de Gruyter & Co., 1951. DM 34.

Book Reviews

AN ATLAS OF GENERAL AFFECTIONS OF THE SKELETON. Sir Thomas Fairbank, D.S.O., O.B.E., M.S., Hon.M.Ch.(Orth.), F.R.C.S. Edinburgh, E. & S. Livingstone Ltd. 55 shillings; Baltimore, The Williams and Wilkins Co., 1951. $10.00.

This comprehensive Atlas will be welcomed by orthopaedists everywhere. It is hardly possible to do justice to the wealth of material, particularly the superior illustrations, here included. The most common disorders are described as well as the most rare, even including those of which only one or two cases have been reported. Readers of *The Journal* will be familiar with some of the earlier chapters, which first appeared in the British Volume.

The plan of the chapters in each case follows the same order: a brief description of the entity, followed by a summary of the known facts regarding incidence, etiology, and skeletal distribution. Case histories with detailed roentgenograms are then given. Only the most pertinent references to the literature were selected, although the book represents a vast accumulation of knowledge and extensive research. The author and subject indexes will be found most helpful.

The format, printing, and general make-up of the text are of the same high quality as the illustrations.

THE 1951 YEAR BOOK OF ORTHOPEDICS AND TRAUMATIC SURGERY (November, 1950–November, 1951). Edited by Edward L. Compere, M.D., F.A.C.S. Chicago, The Year Book Publishers, Inc., 1952. $5.50.

In *The 1951 Year Book of Orthopedics and Traumatic Surgery*, the editor, Dr. Edward L. Compere, has maintained the same high standards of the previous years. The organization and format remain essentially the same. The summaries of articles are on the whole excellent, well illustrated, and supplemented with appropriate editorial comment. In the space of 360 text pages, the editor has covered the literature for the year ending November 1951 in an adequate fashion. The book furnishes a helpful review and ready reference for the busy practitioner and as such is recommended to all who are concerned with this subject.

METABOLIC INTERRELATIONS. Transactions of the Second Conference, January 9–10, 1950. Edited by Edward C. Reifenstein, Jr., M.D. New York, Josiah Macy, Jr. Foundation, 1950. $3.95.

METABOLIC INTERRELATIONS. Transactions of the Third Conference, January 8–9, 1951. Edited by Edward C. Reifenstein, Jr., M.D. New York, Josiah Macy, Jr. Foundation, 1951. $4.00.

These two books are transcripts of the conferences on metabolic interrelations held under the auspices of the Josiah Macy, Jr. Foundation Conference Program. The purpose of such conferences, quite apart from the immediate goal of furthering knowledge about metabolic interrelations, is the promotion of meaningful communication between scientific disciplines and the integration of science and scientific knowledge for the enrichment of all branches. Such a multiprofessional approach to the subjects under discussion is at once evident from the listings of the participants.

In these two books are presented the results of investigations on bone (osteogenesis, osteogenetic potency, nature of bone and phosphate rock, electron micrographic studies of bone, and resorption of bone), cartilage, and, particularly, calcification. A few of the men participating in the discussions are Dr. Fuller Albright, Dr. William Bloom, Dr. Richard H. Follis, Jr., Dr. Sterling B. Hendricks, Dr. Harold C. Hodge, Dr. Franklin C. McLean, Dr. R. A. Robinson, and Dr. Marshall R. Urist.

The presentations follow the informal, rather disjointed manner of round-table discussions. Each section is introduced by a brief statement of the problem to be considered and the results of investigation and observation are then presented by means of astute questioning on the part of the participants. The two works, together with the Transactions of the First Conference, will provide an indispensible guide to all who wish to keep abreast with the rapidly increasing knowledge of the nature and origin of bone.

CHIROPODIAL ORTHOPAEDICS. Franklin Charlesworth, F.Ch.S. Baltimore, The Williams and Wilkins Company, 1951. $5.50.

Chiropodial Orthopaedics is devoted to descriptions of various types of appliances developed by the author for the relief of pain and disability of the feet. The construction of protective shields and padded insoles or moccasins by means of liquid latex, sponge rubber, cork, and leather is given in considerable detail. The author presents many ingenious devices for the relief of pressure on bunions, calcaneal spurs, claw toes, and metatarsal callosities. Also described are various corrective devices for toe deformities in children, which are constructed of latex rubber sheeting and surgical sponge. The chapter on shoe fitting and shoe corrections covers the subject well. The value of the methods described is attested to by several case reports which illustrate the manner in which pain and disability from severe deformities of congenital and paralytic origin were eliminated.

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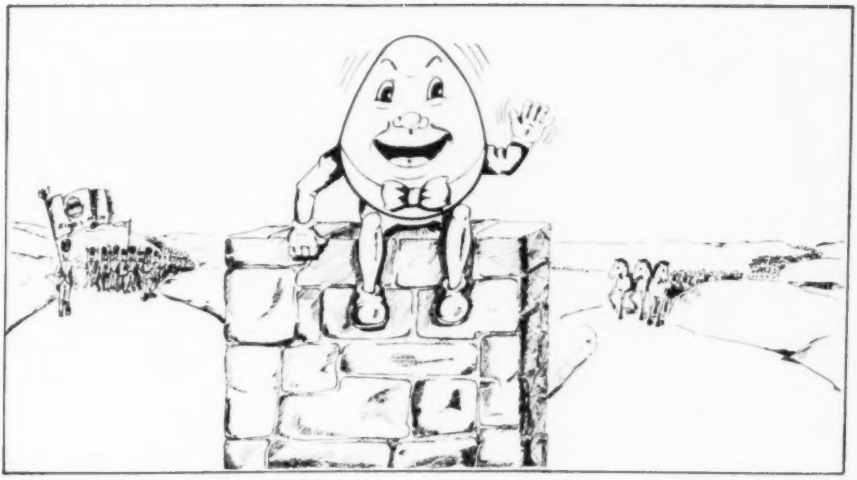

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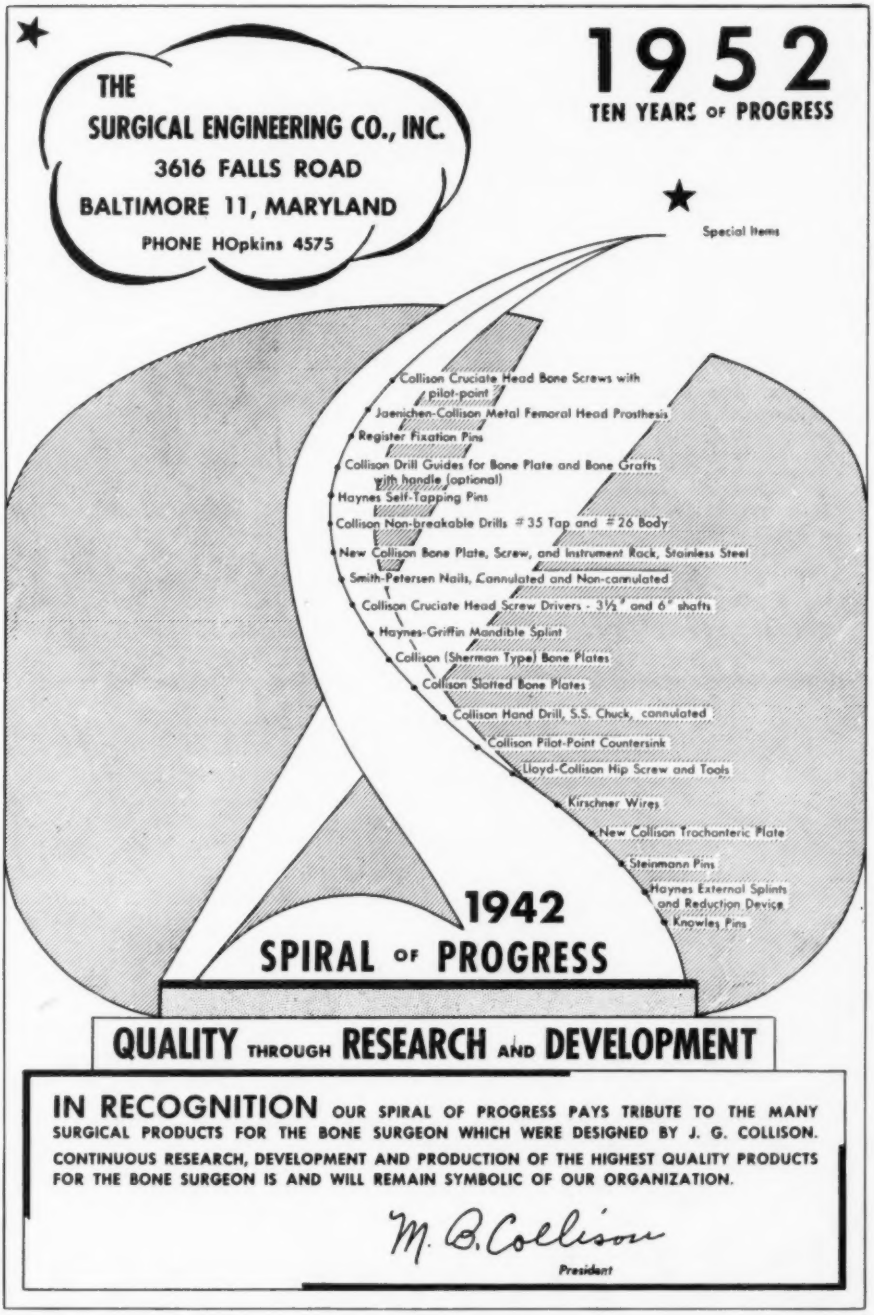
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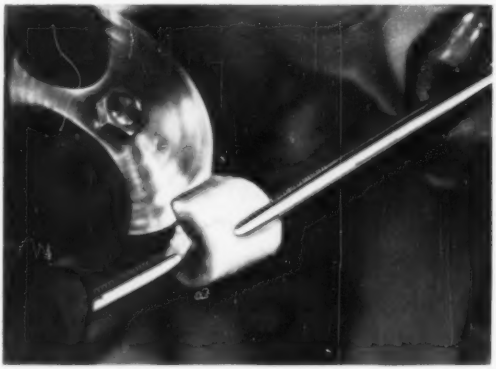

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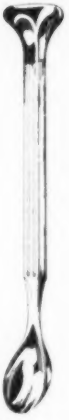

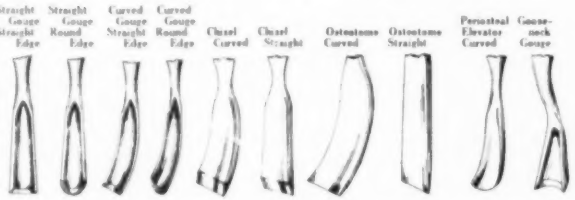

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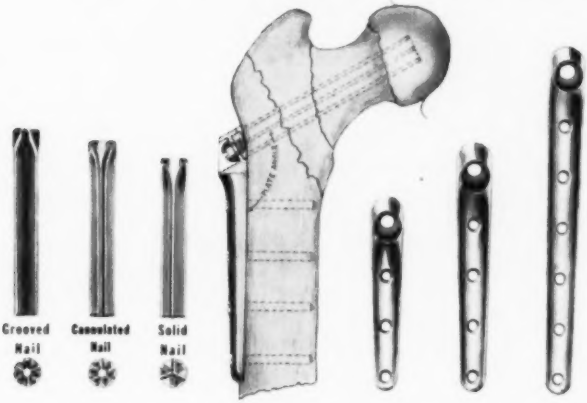

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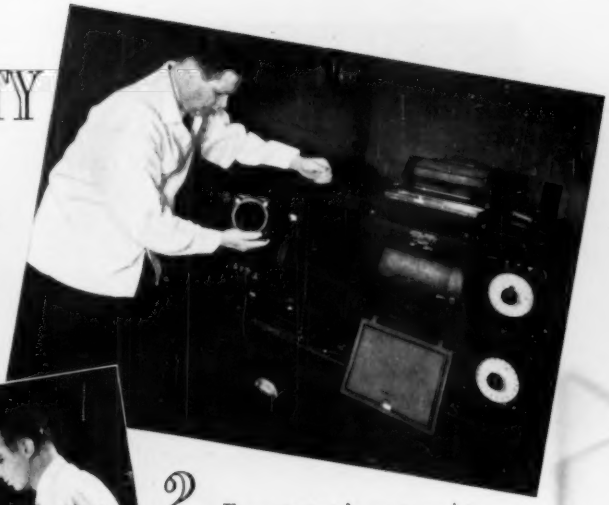

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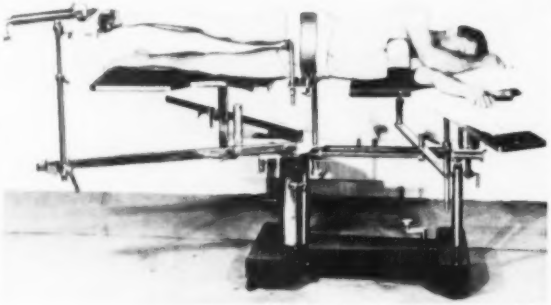

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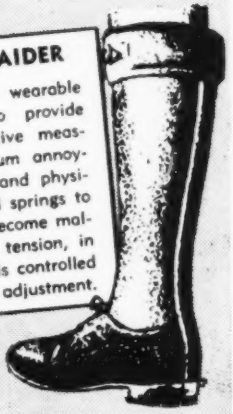

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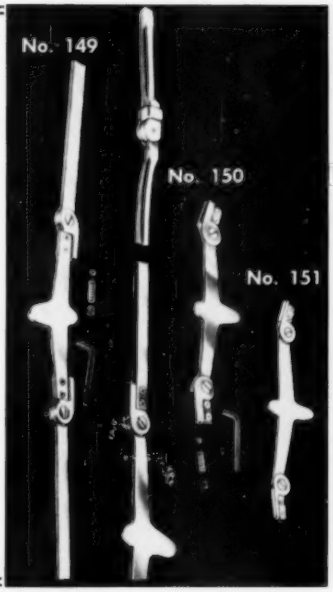

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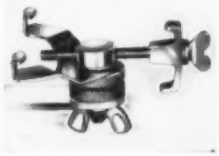

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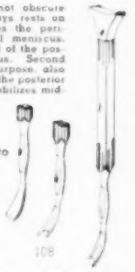

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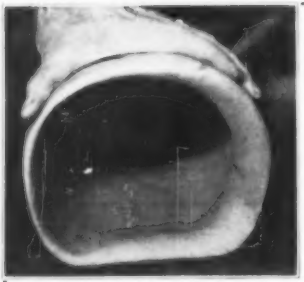

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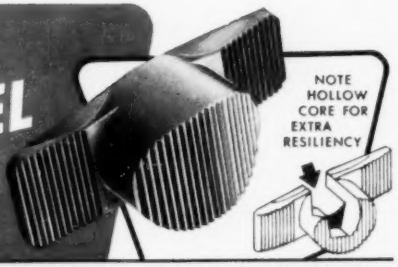

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